Rice and Sturgeon Lakes Nutrient Budget Study

Hydrological Data for the Watersheds of Rice and Sturgeon Lakes 1986-1989

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HYDROLOGICAL DATA FOR THE WATERSHEDS OF RICE LAKE AND STURGEON LAKE

1986 - 1989

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PREFACE

The Kawartha lakes are a large and economically important system of eight large lakes which are located in central Ontario. Sturgeon Lake and Rice Lake are located near the upper and lower ends of the Kawartha Lakes system respectively and both support significant amounts of urban and recreational development. They were chosen for detailed study because of their importance within the system and because both have shown the symptoms associated with excessive nutrient input for several years.

The Rice and Sturgeon Lakes Nutrient Budget Study was initiated to investigate linkages between point and non-point sources of nutrients, water quality, and aquatic life within the lakes and to estimate the impacts of these processes on in-lake water quality.

The study was supervised by the Rice - Sturgeon Lakes Nutrient Budget Technical Committee which had representatives from the Limnology Section (Water Resources Branch) and Central Region of the Ontario Ministry of the Environment and Energy, the Trent Severn Waterway (Environment Canada) and the Kawartha Lakes Fisheries Assessment Unit of the Ontario Ministry of Natural Resources.

This is one of a series of technical reports. These and the summary report (R/S Tech. Rep. No. 13) will provide a technical basis for the management of the Rice Lake and Sturgeon Lake ecosystems and for the use of land and water resources in the Kawartha Lakes region in general. A list of all reports in the R/S Tech. Rep. series is as follows:

1. Hutchinson N.J., B.J. Clark,, J.R. Munro and B.P. Neary 1993. Hydrological data for the watersheds of Rice Lake and Sturgeon Lake.1986 - 1989, 100 pp.

2. Hutchinson N.J., J.R. Munro, B.J. Clark and B.P. Neary. 1993. Water chemistry data for Rice Lake, Sturgeon Lake and their respective catchments. 1986-1989, 169 pp.

3. Hutchinson N.J., B.P. Neary, B.J. Clark and J.R. Munro 1993. Nutrient Budget data for the watersheds of Rice Lake and Sturgeon Lake. 120 pp.

4. Ryback, M. and I. Rybak. 1993. Sediment pigment stratigraphy as evidence of long term changes in primary productivity of Sturgeon and Rice Lakes (Kawartha Lakes). 24 pp.

5. Nicholls, K.H., M.F.P. Michalski and W. Gibson. 1993. Trophic interactions in Rice Lake I: An experimental demonstration of effects on water quality.

6. Limnos Ltd. 1993. Partitioning of phosphorus in *Potamogeton crispus*. 22 pp.

7. Limnos Ltd. 1993. Rice Lake macrophytes: distribution, composition, biomass, tissue nutrient content and ecological significance. 123 pp.

8. Beak Consultants Ltd. 1993. Release of phosphorus from Rice Lake sediments. 31 pp .

9. Limnos Ltd., Michael Michalski Associates and D.J. McQueen. 1993. Trophic interactions in Rice Lake II. Young-of-the-year yellow perch - *Daphnia* interactions, preliminary findings. 101 pp.

10. Badgery, J.E., D.J. McQueen, K.H. Nicholls and P.R.H. Schaap. 1993. Trophic interactions in Rice Lake III: Potential for biomanipulation. 1988 and 1989 .

11. Standke, S. 1993. The zooplankton of Rice Lake and Sturgeon Lakes, 1986-1988, Kawartha Lakes, Ontario .

12. Nicholls, K.H. 1993. The phytoplankton- water quality relationships of the Kawartha Lakes, 1972-1989.

13. Hutchinson, N.J., K.H. Nicholls and S.H. Maude, 1993. Rice and Sturgeon Lake Nutrient Budget Study: Summary and recommendations.

SUMMARY

A hydrologic budget is presented for Rice and Sturgeon Lakes for the period of June 1, 1986 to May 31, 1989. All input and output terms are given for monthly, seasonal and annual totals and the accuracy of the balance presented. Discharge of major inflows and outlets to each lake were measured and changes in storage calculated from measurements of lake level. Precipitation to the surface of each lake was measured and evaporation calculated as the residual term in the energy balance for each lake. The residual or unexplained portion of the hydrologic budget was 3.0 - 9.0% for Rice Lake and -6.7 - 6.0% for Sturgeon Lake when expressed on an annual basis. The residual error was much larger on a monthly and seasonal basis. Water yield was not significantly related to land use characteristics in 11 small sub-watersheds of both lakes. Daily estimates of each term of the hydrologic budget will be used to calculate a nutrient budget for each lake.

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INTRODUCTION

The Rice and Sturgeon Lakes Nutrient Budget Study was initiated by MOE in 1986 with the participation of MNR and Parks Canada. Objectives of the study were to:

1). Construct a detailed nutrient budget for Rice and Sturgeon Lakes.
2) Link the nutrient inputs and outputs to water quality in each lake and in particular to levels of blue-green and other planktonic algae and to rooted aquatic macrophytes.
3) Estimate the impact of Sturgeon and Rice Lakes on the water quality downstream.
4) Develop a nutrient management plan for each lake and make recommendations on the necessity of controlling point and non-point source nutrient inputs.

This report presents the hydrological data collected for Rice and Sturgeon Lakes between June 1, 1986 and May 31, 1989. Quantitative hydrologic data were required as input to the nutrient mass balance model for each lake. In addition, hydrologic budgets for monthly, seasonal and annual periods were constructed for comparison with the nutrient budgets, to gain further insight into the processes working in each lake, and to explore various management alternatives for each lake.

The components of the hydrologic cycle are related by the water balance equation, an expression of the principle of the conservation of mass. For a lake, this equation can be written as:

$$\Delta S = P + R + G - O - E$$

where
P = *precipitation onto the lake surface*
R = *surface runoff into the lake*
G = *net ground water gain by the lake*
O = *outflow from the lake*
E = *net evaporation from the lake*
ΔS = *change in lake storage, or volume*

Mass balance budget models, whether quantifying the flux of nutrients or water through a lake, require detailed data on all inputs, outputs and in-lake processes such as storage or release. Balance between input and output terms, after correction for storage terms, gives the modeller confidence that the model is correct and can be used to explore management alternatives.

This report presents water balances determined for three consecutive 12 month periods between June 1, 1986 and May 31, 1989. The June to May hydrologic year was chosen to minimize the effects of snowpack storage and spring melt on the hydrologic balance, as these events are complete by June 1. Although data collection was started in February 1986, complete records for the entire network were not available until April 1986. The period of incomplete record, and the April-May 1986 records are not included in this report.

Hydrologic balances were also calculated for monthly and seasonal periods of observation. Seasonal totals were calculated for summer (June, July, August), autumn (September, October November), winter (December, January, February) and spring (March, April, May).

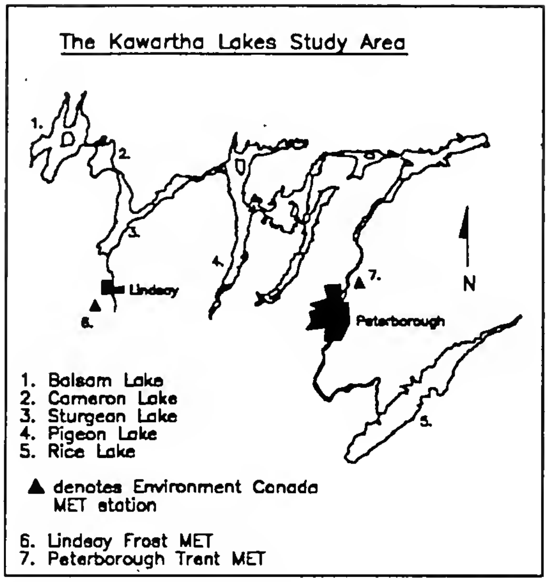

Figure 1: The Kawartha Lakes region showing location of Rice and Sturgeon Lakes.

This report presents data on water balances only. Water chemistry and nutrient budget (ion balance) data are presented in two separate volumes (Hutchinson et al. 1993 b&c). Biological data are given in Nicholls et al. 1993 and all data are summarized in the final report of the Rice and Sturgeon Lake Study (Hutchinson et al. 1993d).

DESCRIPTION OF STUDY AREA

Rice and Sturgeon Lakes are two large lakes located in the Kawartha Lakes Region of South Central Ontario. They form part of the Rideau-Trent Severn waterway, a 680 km corridor of lakes and connecting waterways extending from Port Severn on Georgian Bay to Trenton on the Bay of Quinte and extending northeast to Ottawa. The location of Rice and Sturgeon Lakes is shown in Figure 1.

The surface area of Sturgeon Lake is 4710 ha and it drains a watershed area of 476,377 ha (Table 1). The major inflow to Sturgeon Lake is the outlet of Cameron Lake at Fenelon Falls (Figure 2). This drainage is predominately from forested Precambrian Shield areas in the basins of the Gull River and Burnt River, which discharge into Balsam and Cameron Lakes respectively. The Scugog River drains

Scugog Lake and discharges into Sturgeon Lake at Lindsay. The Scugog River, and the remaining portions of the Sturgeon Lake watershed, drain mixed agricultural, wetland and forested land within the Oak Ridges Moraine, the Till Plain, the Lowland Plain and the Limestone Plateau (Kawartha Region Conservation Authority 1982). Smaller sections of the immediate watershed of Sturgeon Lake are drained by numerous small streams (Figure 2).

From the outlet of Sturgeon Lake at Bobcaygeon, water flows through Pigeon, Buckhorn, Lower Buckhorn, Lovesick, Stony and Katchewanooka Lakes; entering the Otonabee River at Lakefield. From Lakefield, the Otonabee River flows through the City of Peterborough and empties into Rice Lake at Campbelltown.

The drainage area between Sturgeon and Rice Lakes receives runoff from the Precambrian Shield via many creeks, including Jack Creek, Eels Creek and the Mississagua River, but the majority of drainage is from mixed agricultural, forested and wetland areas overlying till plains and sedimentary rock. Rice Lake hydrology is driven mainly by discharge from the Otonabee River with small inputs from the Indian and Ouse Rivers on the north shore (Figure 3). A total of 58 smaller creeks flow into Rice Lake from the immediate watershed. Two of these were monitored to estimate total runoff from this source. They will be described in the next section.

Table 1: Mean depth, volume, surface and watershed area, and residence time for Rice and Sturgeon Lakes.

Rice Lake	Lat. 44 12 Long 78 10	
	Mean Depth	2.4 m
	Volume	2.4×10^8 m3
	Surface Area	10,010 ha
	Watershed Area	914,125 ha
	Residence Time	33.9 days
Sturgeon Lake	Lat. 44 28 Long 78 43	
	Mean Depth	3.8 m
	Volume	1.8×10^8 m3
	Surface Area	4,710 ha
	Watershed Area	476,377 ha
	Residence Time	38.6 days

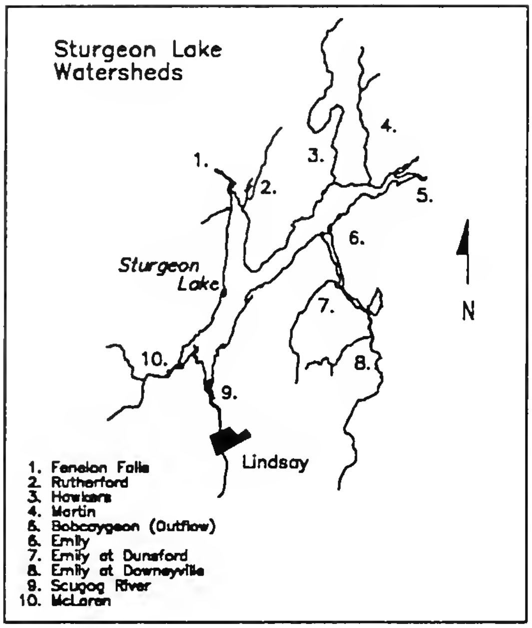

Figure 2: Location of the Sturgeon Lake hydrology monitoring network.

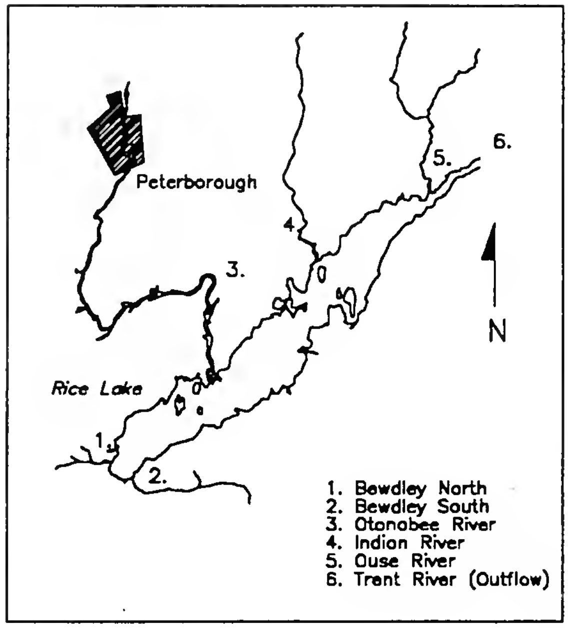

Figure 3: Location of the Rice Lake hydrology monitoring network

Rice Lake covers a surface area of 10,010 ha and drains a total of 914,125 ha (Table 1). From its outlet to the Trent River at Hastings, water flows to the Bay of Quinte and Lake Ontario at Trenton.

The watershed of Rice Lake is regulated by a series of dams. These are located on every lake in the Trent-Severn system and on many lakes in the headwaters in Haliburton and Victoria Counties to the north. The Trent-Severn Waterway requires a regulated flow of water mainly for navigation purposes, but the hydrologic budget is also managed for power generation, flood control, recreation and fisheries management. The volume of total flow which is regulated allowed flow from major tributaries to be estimated using existing records of Trent-Severn Waterway, Parks Canada. These will be described in detail in subsequent sections of the report.

The climate of the Kawartha Lakes system could be described as humid continental and is located within the Simcoe-Kawartha Lakes climatic zone (KRCA 1982). Long term (1951-1980) annual precipitation is approximately 850 mm per year, and 20-25% of that falls as snow between November 1 and April 30 (Table 2, from Env. Canada. 1981). Average daily temperature is 19.75°C for July and -8.85°C for January. Runoff depth is approximately 300 mm per year (Hydrological Atlas of Canada).

Table 2: Summary of long-term hydrometeorological characteristics of the Rice and Sturgeon Lakes Study area.

	Lindsay	Peterborough
Temperature		
Average Daily (July)	19.7	19.8
Average Daily (Jan)	-8.9	-8.8
Precipitation		
Rainfall (mm)	656.3	642.2
Snowfall (water equiv. mm)	201.9	161.7
Total Precipitation (mm)	856.4	797.7
Std. Dev. Total Precipitation	105.1	98.3

Methods

Methods employed for collection and analysis of hydrological data were adapted from those used in the Ontario Lakeshore Capacity Study and the Acid Precipitation in Ontario Study (Scheider et al. 1983, Locke and Scott 1986) for smaller tributary streams, lake storage and evaporation. Discharge from major inflows and outflows was obtained by Parks Canada staff, using methods specific to each major tributary.

Precipitation

Daily records of total precipitation (mm) were obtained from the Environment Canada meteorological stations closest to Sturgeon and Rice Lakes. The Sturgeon Lake hydrology budget used data from the station at Sir Sandford Fleming College in Lindsay (Lindsay-Frost, Station Number 6164433). Data from Trent University in Peterborough (Peterborough-Trent, Station Number 6166455, see Figure 1) were used in the Rice Lake calculations. The contributions of precipitation to the hydrologic budget of each lake were calculated by multiplying monthly total precipitation depths by the surface area of each lake. These monthly volumes were summed to produce seasonal and annual totals.

Runoff

Daily records of surface runoff , or stream flow, were obtained from a hydrology monitoring network around each lake (Figures 2 and 3). Inflow and outflow through the major tributaries of the system; the Cameron Lake outlet at Fenelon Falls, the Sturgeon Lake outlet at Bobcaygeon, and the Scugog, Otonabee and Trent Rivers, were determined by staff of the Trent-Severn Waterway, Parks Canada, using techniques described below. Daily records of discharge for the Ouse River were obtained from the Water Survey of Canada. The small streams were equipped with continuous stage recorders and hydrographs were developed using techniques described below. Runoff from ungauged portions of each watershed was estimated by prorating areally weighted runoff measurements from gauged subwatersheds of the same lake. The characteristics of all hydrology monitoring sites are given in Tables 3 & 4 (Appendix 1).

Continuous Stage Records

Each stream on the hydrology network, with the exception of those monitored by Parks Canada or Water Survey of Canada staff, was outfitted with a stilling well, staff gauges and a continuous water level recorder. Leupold-Stevens A-71, float activated chart recorders were used at all sites except for the Indian River, Emily Creek at Downeyville and Martin Creeks, where float-activated electronic data loggers were used. Their operation is described in other sections of the report. All stilling wells were outfitted with infrared heat lamps suspended over the water, heating cables and styrofoam vapour barriers to facilitate winter operations. Biweekly site tours were scheduled for regular network maintenance. Additional maintenance included backflushing of stilling wells, and level surveys of each site twice yearly.

Strip charts were marked with staff gauge readings and site observations on each site visit. They were collected at three month intervals, documented according to the "Automated Stream Flow Computations" manual (Environment Canada, 1974) and the trace converted to digital output. The Fortran computer program "STREAMS" (Water Survey of Canada 1977) was used to produce a continuous daily record of stage height from the digital trace plus documentation, and to convert stage to discharge estimates.

All streams records were edited to a tolerance of ±2 mm between each chart point and corresponding staff gauge reading for the ice-free period. A tolerance of ±4 mm was allowed during the period of ice cover. Larger errors were allowed during the spring freshet when the alternative was to discard the record, or when it could be established that the error was due to a lag in the hydrograph record produced by the recorder.

Discharge Measurements

Each stream was rated by measuring the discharge of water over the full range of stage heights. Exceptions to this were major inflows and outflows (Cameron Lake outlet at Fenelon Falls, Sturgeon Lake outlet at Bobcaygeon,the Otonabee River and the Trent River). These were either too large for conventional rating or had backwater effects. The Ouse River was already rated and instrumented by the Water Survey of Canada. Rating curves were attempted for the Scugog River and Emily Creek but these were abandoned when no relationship emerged and alternative methods were used. For the Scugog River, no relationship between measured discharge and stage height, measured immediately above and below Lock 33 and approximately 1 km upstream was observed. The guaging site at the mouth of Emily Creek was too heavily influenced by wave and seiche action from Sturgeon Lake to produce a reliable relationship between stage and discharge.

All streamflow estimates >2 L/s were determined by standard stream-guaging methods; where the average velocity of water in a stream over a known cross-sectional area is used to determine the volumetric discharge. Velocity was measured with either a Teledyne Gurley Pygmy Model 625, an Ott C2 or an Ott C31 current meter. Choice of meter and of propeller was dependent on stream volume and velocity.

Stream velocity was measured at intervals ranging from 0.20 to 1.0 m across a defined section of stream. Interval width was chosen to allow approximately 20 velocity measurement panels for each stream. At each interval, depth of water was recorded and velocity measured at approximately 60% of stream depth by counting revolutions of the meter over 40 seconds. Meters were calibrated at the start of the study and again in mid-study.

Discharge was calculated by the mean section method (Locke and Scott 1986), using a microcomputer program. Data editing procedures are described in a subsequent section.

Construction of Rating Curves

Preliminary analysis and editing was performed on a plot of measured discharge values vs. stage height for each stream. Most values formed an obvious curve but those lying off the curve were identified and checked for errors.

Off-curve values were checked against field notes to determine if they corresponded to a period of ice influence, if data had been transcribed incorrectly from field notes or if other factors such as debris blockage, construction or beaver activity were responsible for the deviation. Points which remained off the curve and which were not accounted

for by ice or other factors were discarded as field errors. Less than 5% of the instantaneous discharge measurements were discarded in this manner.

Stage-discharge curves were optimized as a least squares fit to an exponential curve, using customized procedures developed for the Dorset Research Centre hydrology data base. The form of the stage-discharge line was $Q = A*S^P$, where Q = discharge in L/s, S = stage height in metres, and A and P are coefficients determined by successive iterations in the curve fitting process. The upper range of stage height and the stage height of zero discharge, if known, were entered by the user. If zero discharge had not been reliably measured it was selected by iteration about candidate minimum stage heights; using the lowest value of the residual sum of squares as the selection criterion.

Multiple stage curves were identified visually from obvious breaks in the stage-discharge relationship. The specific stage height marking minimum flow in the upper stage was selected, as before, by successive iterations to find the stage height producing the minimum residual sum of squares in the exponential line fit. The output of the line fitting routine was retained in the hydrology data base and applied to the final stage heights to calculate discharge figures (Tables 5 & 6, Appendix 1).

Missing Data

Failure of the monitoring equipment, errors in the fit of the hydrograph to observed values or rejection of segments of the hydrograph due to beaver dams or construction activity all produced short periods of missing data for each of the small, monitored streams (Tables 3,4, Appendix 1). Data for the missing periods were synthesized as described below.

Interpolation was used to fill missing periods of 1-2 days if no rainfall or snowmelt events occurred. Interpolation involved joining values on either side of the missing period with a straight line.

Regression techniques were used to estimate missing data over longer periods. A custom program on the Dorset minicomputer, "Estimate", was used to fill the majority of missing segments. This program examined complete hydrograph sections on either side of the missing segment and compared these to complete records measured in other nearby watersheds. Daily discharge plus 1 day lags or leads in these nearby streams were used as independent variables. The program used stepwise linear regression techniques to synthesize missing segments, based on the fit of complete hydrograph segments.

All estimated data were compared to real data to determine if the results were reasonable when inserted into the measured hydrograph. In many cases the "Estimate" program produced acceptable fits of missing to observed values ($r^2 > 0.9$).

In cases where results were not acceptable, where low r^2 values indicated a poor fit or where there was not sufficient continuous data from adjacent streams to make predictions, a modified procedure was used.

The modified estimation method compared discharge of all candidate streams during the season of interest over the entire three-year study period instead of for a small period on either side of the missing segment. In this way, data from adjacent streams which shared similar seasonal characteristics was pooled to estimate the missing segment. This procedure also used stepwise linear regression for the final comparison and choice of predictive streams.

Rice Lake Hydrology Network: Inflows

The Rice Lake monitoring sites are illustrated in Figure 3 and watershed areas are given in Table 3, Appendix 1.

Otonabee River discharge was measured at Ontario Hydro's Auburn Generating Station at Peterborough (Figure 4). At flows above 51.7 cubic metres per second ($m^3.s^{-1}$), the measured flow was adjusted using the following formula:

$$Q_{adjusted} = 0.583 \cdot Q_{measured}^{1.088}$$

This relationship was developed by Acres Consulting for a 1972 survey of the Trent-Severn Waterway, to estimate flows in excess of the capacity of the Auburn Generating Station. It has been used since Water Survey of Canada discharges for the Lakefield gauging site became unreliable in 1984 (Bruce Kitchen, Trent-Severn Waterway, Parks Canada, pers. comm.).

A total of 68,600 ha of incremental drainage area are present between the Auburn Station in Peterborough and Rice Lake (Figure 4). Discharge estimates for this area were determined by prorating the daily discharge measured for Jackson Creek (drainage area = 11,480 ha) by WSC using the formula:

$$IncrementalDrainage = JacksonCreek \cdot \frac{68600}{11480}$$

This method of direct transfer of daily discharge was used because the majority of the incremental drainage area is made up of several small watersheds which would display similar drainage characteristics to those of Jackson Creek.

Total discharge for the Otonabee River was then calculated as:

$$Total\ Discharge = Discharge\ at\ Peterborough + Incremental\ Discharge$$

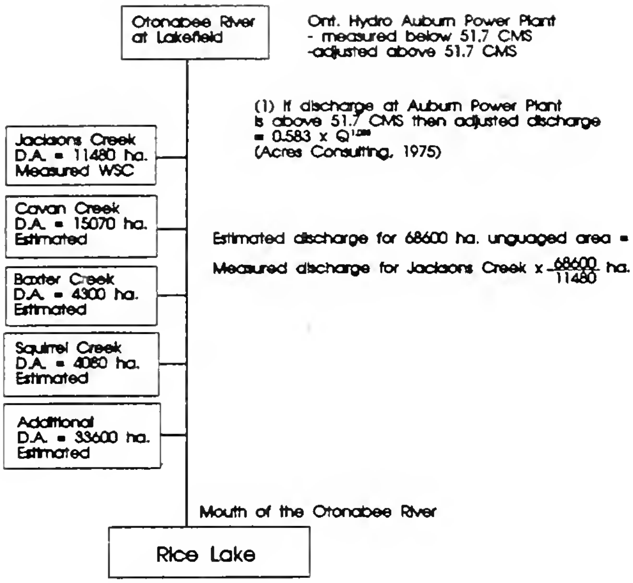

Figure 4: Schematic diagram of method used by Parks Canada to calculate daily discharge to Rice Lake from the Otonabee River

The Ouse River at Westwood is a permanent monitoring station of the Water Survey of Canada (Station 02JH003). Daily estimates of discharge were obtained from a permanent record of stage height and a stage-discharge relationship kept by WSC.

The Indian River was also monitored as a significant tributary of Rice Lake at the Hope Mill, upstream from the Village of Keene. Hourly recordings of stage height were made on an electronic data logger maintained by the Otonabee Region Conservation Authority. A float and weight system were installed in a stilling well located inside the old Hope Mill, immediately downstream of the dam storing water to run the mill. All data stored on the logger for the period of June 28 - September 1, 1986 were lost and so flow for that period was estmated using techniques described previously.

Spot discharge measurements and simultaneous staff gauge readings were made at a bridge 200 m downstream of the datalogger. The stream was rateable without the installation of a weir because the stream section was rectangular, and was not subject to backwater effects. Since the permanent record of stage height was made at the datalogger it was necessary to convert stage heights taken at the bridge to data logger measurements in order to calculate the stage-discharge relationship. This was accomplished by regressing staff gauge readings against simultaneous datalogger records.

A plot of staff gauge readings vs. simultaneous datalogger records at Hope Mill revealed four distinct relationships between the two over the course of the study (Figure 5).

Regression lines for the four periods of time were as follows:

Mar-Jul 1986:	Datalogger = (0.680*Bridge) + 5.421	r^2 = 0.99
Sep-Dec 1986:	Datalogger = (0.932*Bridge) + 5.366	r^2 = 0.88
Mar-Dec 1987:	Datalogger = (0.817*Bridge) + 5.820	r^2 = 0.98
Mar 88-May 89:	Datalogger = (0.864*Bridge) + 5.600	r^2 = 0.95

A t-test for parallelism (Kleinbaum and Kupper 1978) revealed that the lines for March-December 1987 and March 1988-May 1989 had slopes that were not significantly different ($p<0.01$). The 1987 and 1988-1989 records were thus combined by adding the difference between the intercept values for each line (0.22) to the 1987-1989 values. This produced the following relationship (Figure 5) for the 1987-1989 period of record:

Mar 87-May 89:Datalogger = (0.823*Bridge) + 5.827
$r^2 = 0.96$

The slopes of the staff gauge vs. datalogger relationship were significantly different for the periods April-July 1986, September-December 1986 and 1987-1989. Further data combinations were not possible. In total, three lines related staff gauge readings made at the bridge below Hope Mill to simultaneous data logger stage records made at Hope Mill (Figure 5).

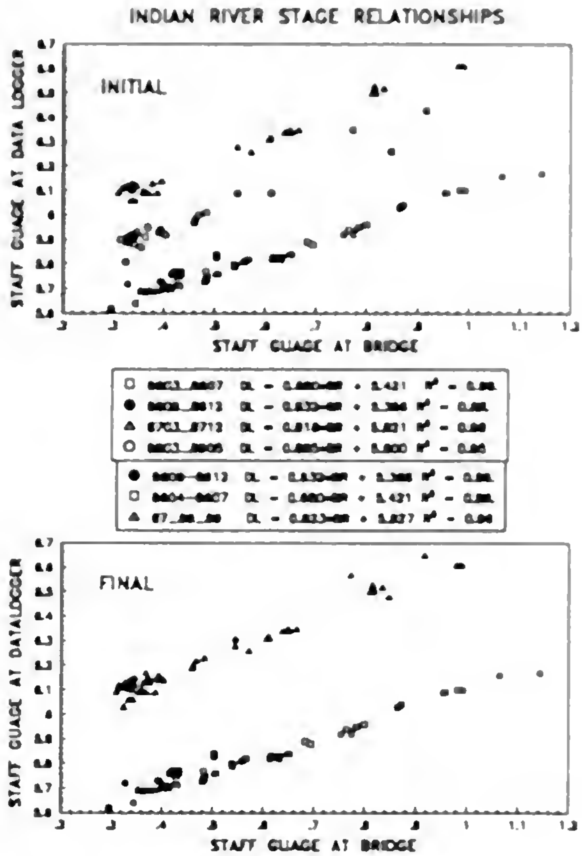

Figure 5: Relationships between stage height of the Indian River (IR1) as measured by the datalogger at Hope Mill and at the staff gauge downstream (1986-89)

The stage records from the staff gauge were converted to equivalent datalogger values using the appropriate relationship prior to calculating the stage discharge relationships for the Indian River. Equation 1 was used prior to July 1986 and equation 2 was used between September 2, 1986 and February 24, 1987. On February 24, 1987, a large increase in apparent stage occurred. No precipitation events occurred in this period and examination of the hydrograph plus the staff gauge readings revealed that the change in relationship was likely related to errors in the datalogger record itself. This event marked the beginning of the 1987-88-89 staff gauge vs. datalogger relationship. A similar event occurred on December 29, 1987

and this data marked the point where the 1988-89 values were adjusted by 0.22 to correspond to the 1987 values.

Stage discharge relationships were calculated from instantaneous discharge measurements made at the Hope Mill bridge and staff gauge readings which had been converted to datalogger records. Four stage-discharge curves were used to cover the three periods of different staff gauge vs. datalogger relationship, plus the period of ice cover on the Indian River. These are shown in Figure 6.

Two small streams at the west end of Rice Lake were monitored in order to estimate the ungauged portion of the Rice Lake watershed. The watersheds of these two creeks contained proportions of forested and agricultural land which were considered representative of the remaining, unguaged portion of the immediate watershed. Cavan Creek, at County Road 9, south of Bewdley (Bewdley South, BYS) drained an area of 2220 ha, of which 7% was forested. The remainder of the watershed was cultivated or in pasture (Table 8, Appendix 1). Discharge measurements were made at a concrete weir 20 m downstream of the stilling well. A two stage rating curve related stage height to discharge. The second stage of the curve corresponded to a change in channel morphometry at a stage height of 0.634 m (Figure 7).

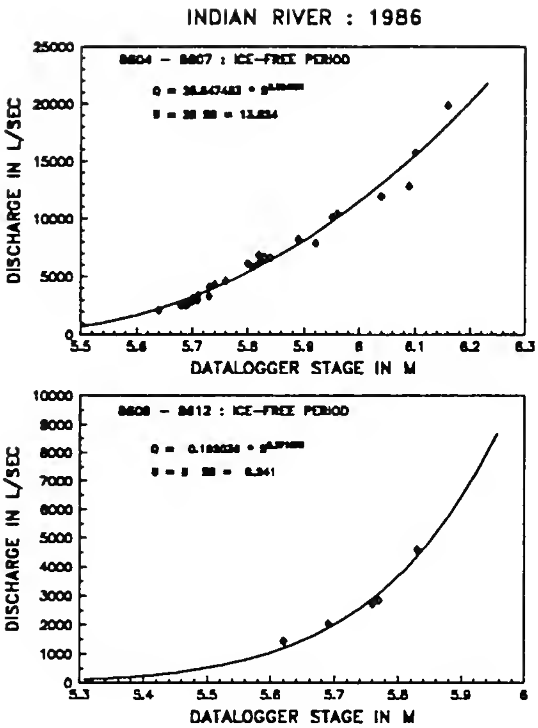

Figure 6a: Stage-discharge curves for the Indian River below the Hope Dam (IR1) for two periods in year 1 of the study

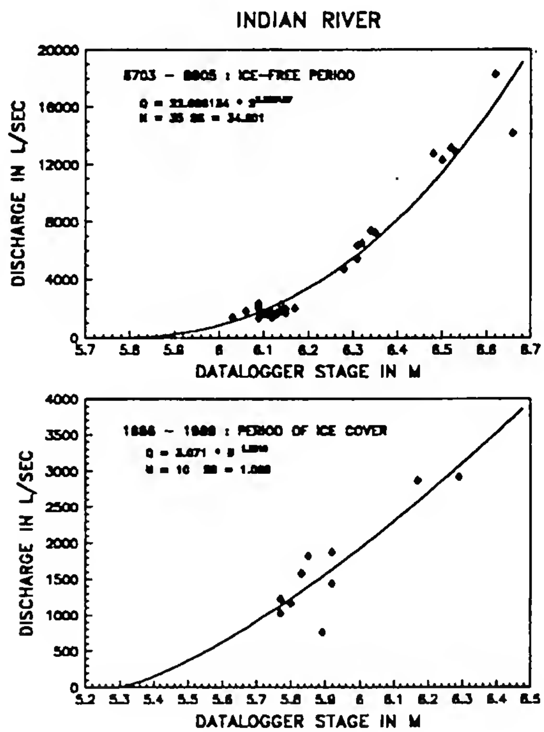

Figure 6b: Stage-discharge curves for the Indian River below the Hope Dam (IR1) for years 2 and 3 and all periods of ice cover during the study

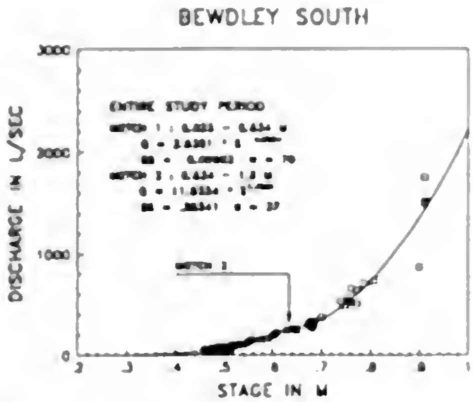

Figure 7: Stage-discharge curve and equation for monitoring station BYS on Cavan Creek at County Road 9 (Bewdley South)

A small stream north of Bewdley (Bewdley North, BYN) was monitored where it passed under Hwy 28. The 631 ha. watershed drained an area which was 53% forested. The remainder was cultivated or in pasture (Table 8). A notched log weir was built 2 m downstream of the concrete culvert beneath Hwy. 28 and the intake for the stilling well was located in the weir pool.

Two separate stage discharge relationships were made for the Bewdley North site (Figure 8). A culvert was placed 15 m downstream of the gauging site in May of 1987 and the backwater effect from this culvert produced a different stage-discharge relationship for the second and third year of the study. Beaver dams 300 m downstream and construction activities 15 m upstream of the level recorder produced ongoing problems with stream flow monitoring so that much of the record had to be estimated. The inlet to the stilling well was severed during construction activity in November 1988. Monitoring revealed that the hydraulic connection between the stilling well and the weir pool was maintained because the clay soils retained an open route for water movement. Errors between the observed and the recorded hydrograph were within the tolerances discussed previously and this portion of the hydrograph was retained.

In total, 11.5% of the 24,734 ha ungauged portion of the Rice Lake watershed was monitored at the Bewdley North and Bewdley South sites (Table 3). Data analysis revealed that the flow regime at Bewdley South was variable and produced unrealistic estimates when prorated to estimate discharge for the unguaged areas. The combined discharge for the Bewdley sites plus the Indian and Ouse Rivers was thus prorated to the ungauged portion of the watershed by dividing the discharge by 2.299, the ratio of guaged to unguaged areas.

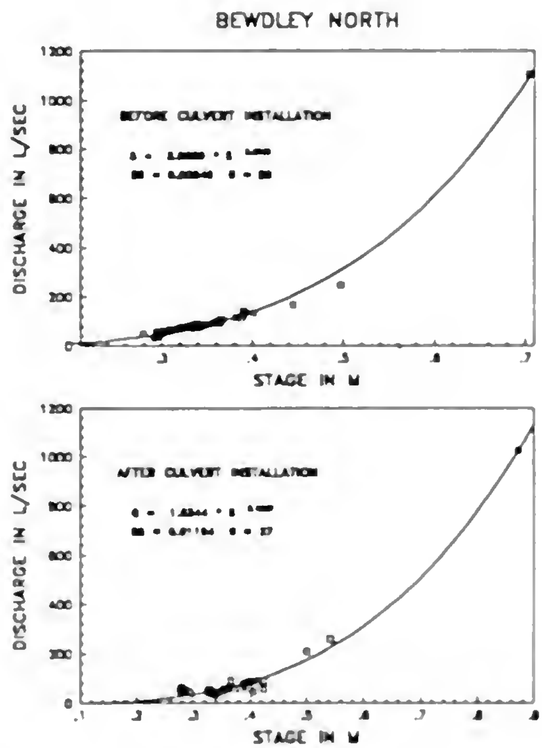

Figure 8. Stage-discharge curves and equations for Bewdley North.

Sturgeon Lake Hydrology Network: Inflows

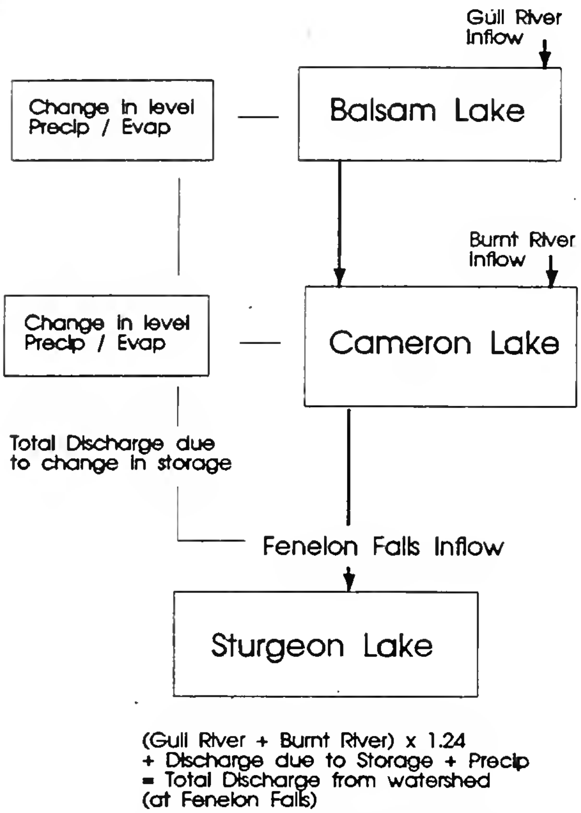

Figure 9: Schematic diagram of method used by Parks Canada to calculate daily discharge of Cameron Lake to Sturgeon Lake at Fenelon Falls

The hydrology network for Sturgeon Lake is illustrated in Figure 2 and summarized in Table 4. Discharge estimates for the major inflows and outflows of Sturgeon Lake were calculated by staff of the Trent-Severn Waterway, Parks Canada, using the methods outlined below.

No discharge measurements were made at the major inflow to Sturgeon Lake at Fenelon Falls. Measurements existed for the inflow of the Gull River to Balsam Lake and for discharge from the Burnt River to Cameron Lake (Figure 9). The combined discharge from these two rivers was multiplied by 1.24 to account for the additional 24% of watershed area between these inlets and Fenelon Falls. This total discharge was added to the changes in storage of Balsam and Cameron Lakes as calculated from water level records. Finally, precipitation and evaporation from the surface of the two lakes were estimated from measurements made at the Lindsay Frost meteorological station of Environment Canada.

Total discharge from Cameron Lake at Fenelon Falls was thus calculated as :

$$Q_{Cameron} = 1.24 * (Q_{BR} + Q_{GR}) + \Delta S_{CB} + precip_{CB} - evap_{CB}$$

where
BR is the Burnt River
GR is the Gull River
CB is (Cameron+Balsam Lakes)
Δ S is change in storage volume

Several stage-discharge rating curves were attempted for discharge of the Scugog River at Lock 33 in Lindsay. Discharge measurements were made from a bridge 700 m downstream of Lock 33. Stage readings were made above and below the dam at Lock 33; either from staff gauges during ice-free periods or from oil gauges during

periods of ice cover. An additional staff gauge and a water level recorder were installed approximately 1 km upstream of Lock 33 at the Mary Street Water Treatment Plant. The stage-discharge relationship was highly erratic, both for stage heights measured at Lock 33 and at Mary Street (Figure 10) and so no rating curve was obtained.

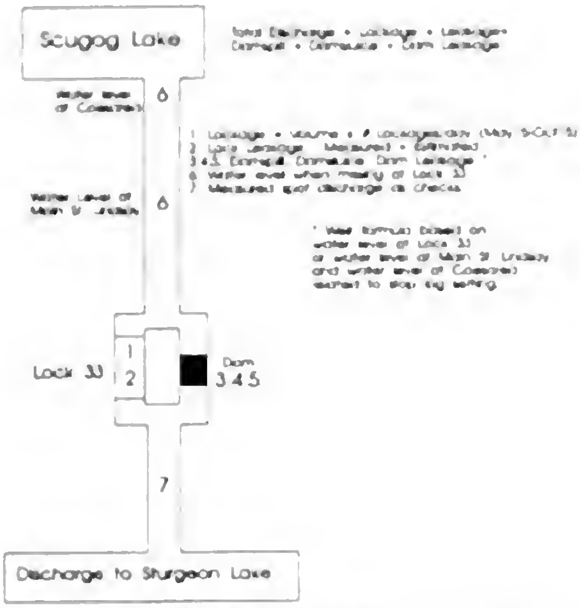

Figure 11: Schematic diagram of method used by Parks Canada to calculate daily discharge of the Scugog River at Lindsay

Discharge estimates for the Scugog River at Lindsay were developed by staff of the Trent-Severn Waterway, Parks Canada. Most of the flow of the Scugog River passed over a weir or through a dam adjacent to Lock 33 (Figure 11). Discharge was calculated for different weir heights (stop log settings) using stage height measured at Lock 33, Mary Street or in Scugog Lake at Caesarea. This discharge was added to an estimate of leakage through Lock 33 which was obtained by gauging and by observation. Finally, lockage discharge was estimated as lock volume x number of lockages for the May 15 - October 15 navigation season. Daily discharge estimates were compared to measured spot discharges as a check on calculations.

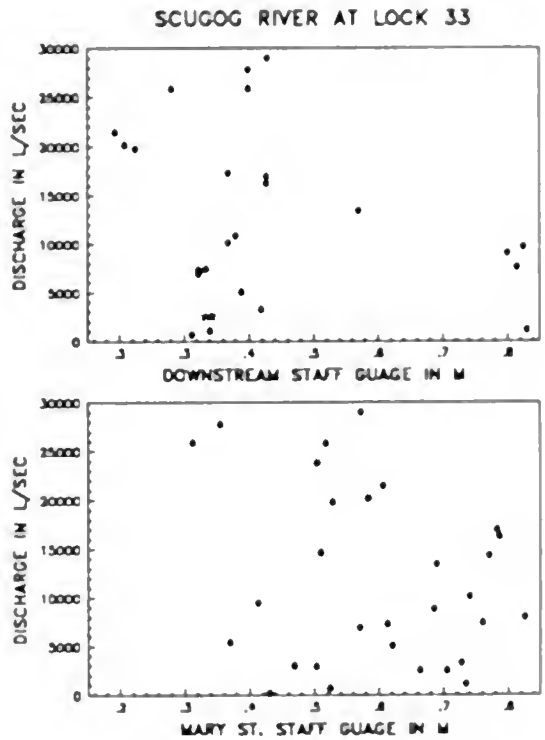

Figure 10: Stage-discharge relationships attempted for station SGW on the Scugog River at Lock 33 in Lindsay

Emily Creek was the largest of the minor Sturgeon Lake tributaries monitored. In the initial six months of the study period a stage-discharge relationship was attempted for the mouth of Emily Creek at Hwy. 36. At this point, however, Emily Creek widens into a complex of small bogs and wetlands along the shore of Sturgeon Lake and is

heavily influenced by wind and seiche action in the lake. No relationship between stage and discharge measured at Hwy. 36 was observed and so calculating a rating curve was not possible. Emily Creek discharge was thus estimated by monitoring the main body of the creek at a site on Victoria County Road 7, north of Downeyville (Emily at Downeyville, EAD) and a tributary creek which passed under Hwy. 36 at Dunsford (Dunsford Creek, DH36). Together, these creeks drained 5211 ha, or 31.2% of the Emily Creek watershed (Table 4, Appendix 1). The sum of their two discharges was multiplied by 3.21 to estimate the discharge for Emily Creek (EY1).

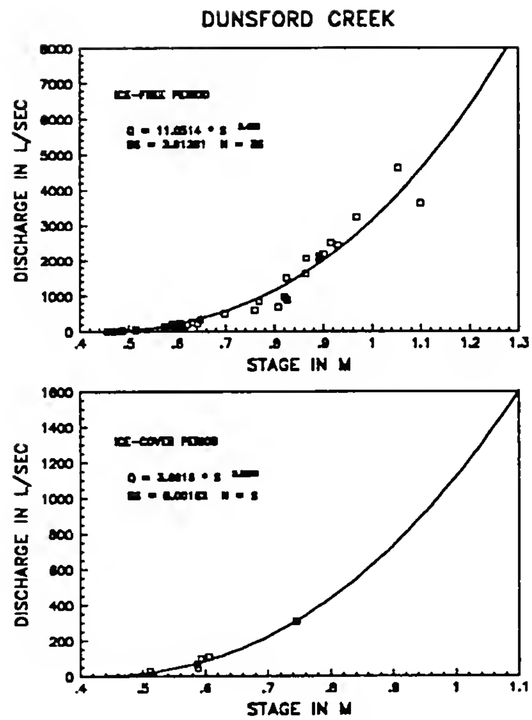

Figure 12: Stage-discharge curve and equation for station DH36 on a tributary of Emily Creek near Dunsford (Dunsford Creek)

The Dunsford Creek tributary monitoring site was located at Hwy. 36, 3 km east of the town of Dunsford, approximately 100 m downstream of a small control structure and farm pond. No gauging structure was built and most discharge measurements were made across the bottom of a rectangular concrete culvert under Hwy. 36. The stilling well was secured to the downstream side of this culvert. During periods of low flow a gauging section 100 m downstream was used, where the creek was one-quarter the width as it was at the highway. The Dunsford Creek monitoring site was established in September 1986 and so discharge for the first three months of the study was estimated from that of other Sturgeon Lake tributary streams, using methods described elsewhere. Two rating curves were constructed for the Dunsford Creek site. Curve 1 covered the entire ice-free period of the study and Curve 2 covered periods where the creek was covered with ice (Figure 12).

No gauging structure was built at the Emily Creek at Downeyville site. Instead the stilling well intake and gauging section were located 2 m downstream of a concrete culvert beneath County Road 7 in a smooth portion of the channel. The water level record for June 1986 to December 1987 was stored on an "Envirolab" Model DL-120-MCP digital datalogger. Datalogger readings were periodically reset to simultaneous

stage height from a staff gauge mounted in the creek. For the period of datalogger operation, the two stage heights were related as:

Datalogger = (0.9779 x Bridge) - 0.0011; r^2 = 0.976, $p < 0.00001$

The data logger stages were converted to staff gauge stage by this relationship prior to calculating discharge. The datalogger ceased operation in November 1987 and a Leupold-Stevens A-71 recorder was installed for the duration of the study.

Three rating curves were developed for the Emily at Downeyville site. Curve 1 was a two stage relationship covering normal flow for the entire study period (Figure 13). The second stage of the curve started at a stage height of 0.64 m, and corresponded to increased volume in the stream channel. Curve 2 covered the extended drought period from June 10 to December 20, 1988. Curve 3 covered periods when the stream was ice-covered.

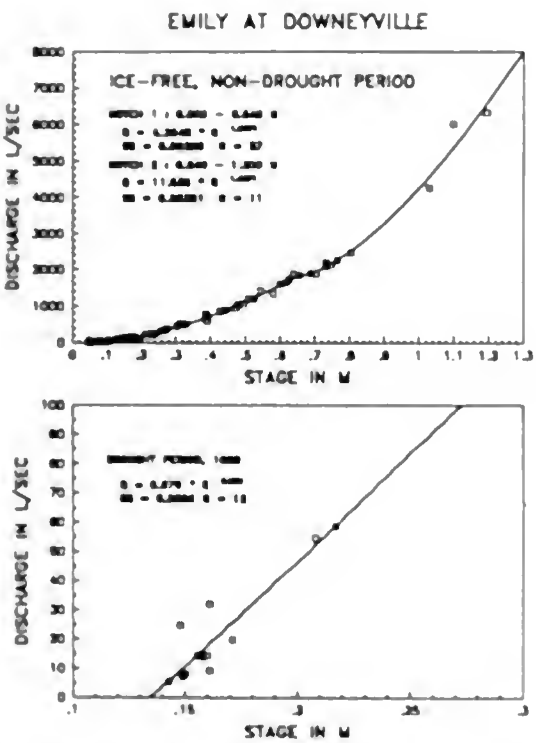

Figure 13a: Stage-discharge curves and equations for Emily Creek near Downeyville (EAD) for ice-free periods

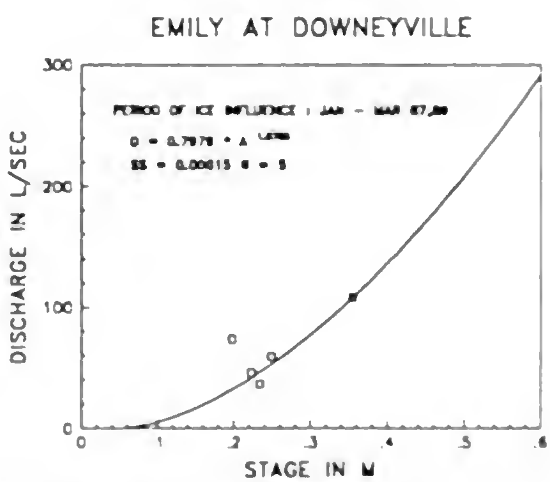

Figure 13b: Stage-discharge curve and equation for Emily Creek near Downeyville Ontario (EAD) for periods of ice cover

Discharge from four small streams was monitored to determine their contribution to Sturgeon Lake, and to estimate the ungauged watershed contribution. These were McLaren, Hawkers, Martin and Rutherford Creeks.

The McLaren Creek hydrology site was located where the stream passed under the first concession upstream of Hwy. 35, north of the town of Lindsay (Figure 2). A rectangular concrete culvert served as a stream guaging section and the stilling well intake was located 1 m downstream. A staff gauge was attached to the side of the culvert. A supplementary gauging site was located 500 m upstream for use in low flow periods. Two rating curves were developed for McLaren Creek. Curve 1 was a two-stage curve, with the second segment at 0.36 m corresponding to changes in channel morphometry. Curve 2 described periods of ice cover in March 1986 and from January to March 1989. In the remaining periods of ice cover, the stage discharge relationship was described by Curve 1 (Figure 14).

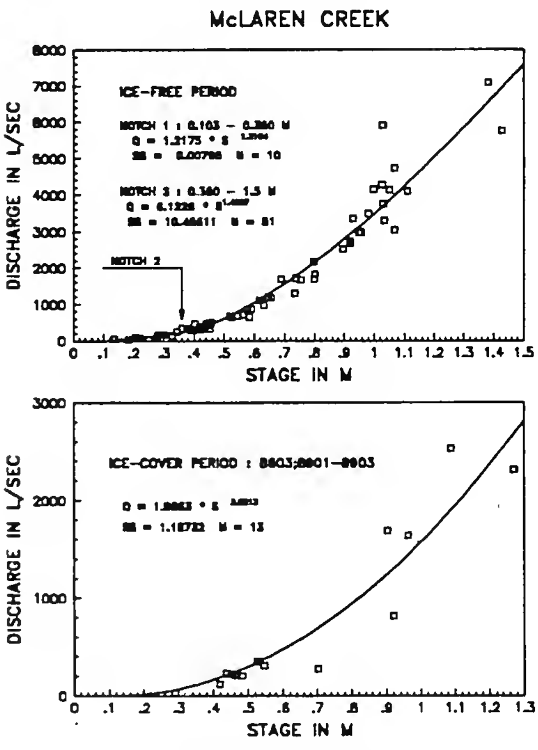

Figure 14: Stage-discharge curves and equations for McLaren Creek at the first concession upstream of Hwy. 35 (ML1)

The Martin Creek hydrology monitoring site was located at Victoria County Road 8, east of Bobcaygeon. Stage height was recorded on an "Envirolab" digital datalogger, Model DL-170-MCP for most of the study period. Datalogger malfunctions resulted in 297 lost days of data over the 1157 days of the study. In addition, the datalogger was replaced with a Leupold-Stevens A-71 chart recorder for the periods of October 1, 1987-November 30, 1987 and April 1, 1988-May 31, 1988, and with an F-type chart recorder for May 19, 1989-June 1, 1989. The stilling well was attached to the downstream side of a rectangular concrete culvert beneath the highway and the gauging section established adjacent to it. Staff gauge stage heights were related to datalogger stage by the following relationship:

Datalogger = (0.993 x staff gauge) - 0.0052, $r^2 = 0.977$, $p < 0.000001$

Datalogger records were converted to staff gauge readings using this equation prior to discharge calculation. A two-stage rating curve, with the second stage beginning at 0.399 m described the stage-discharge

relationship for the ice-free period of study (Figure 15). A second curve was used for the December-March period of ice cover in each of the three study years.

The Hawkers Creek monitoring site was located 4 km east of Martin Creek, on County Road 25. It too, consisted of a rectangular concrete culvert used for a gauging section. A stilling well and chart recorder were attached to the downstream side of the culvert. No problems were encountered with this site until March of 1989 when a large piece of ice destroyed the stilling well during the spring freshet. Twice-daily gauge readings by a local observer made up the stage record for the final portion of the study. One, single-stage rating curve described the stage-discharge relationship of Hawkers Creek for the entire period of study (Figure 16).

The Rutherford Creek monitoring site was located where the creek passed under Victoria County Road 25. The gauging section was located upstream of a round steel culvert and stage height was determined as the distance to the water surface from a hole cut in the top of the culvert. A steel V-notch plate across the downstrean end of the culvert formed the weir pool where the inlet to the chart recorder was located. Stage was calculated as (1.9 m - measuring point distance) and used to calculate a single rating curve for the entire period of study (Figure 17).

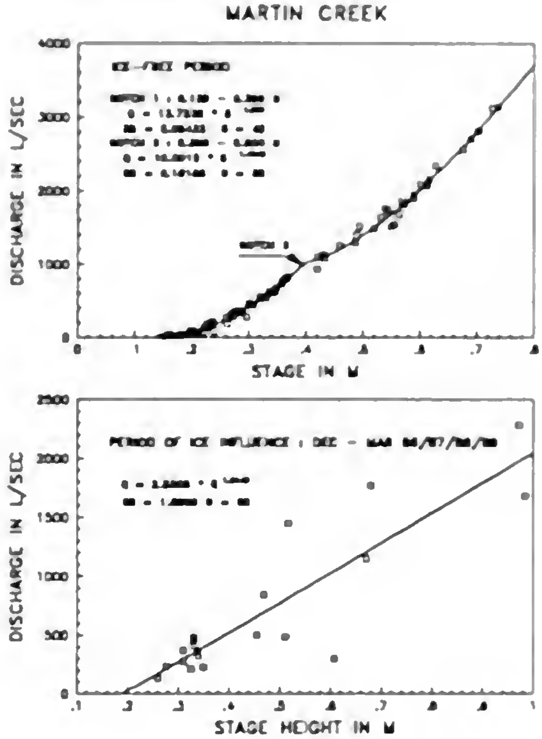

Figure 15: Stage-discharge curves and equations for Martin Creek at County Road 8 (MN1)

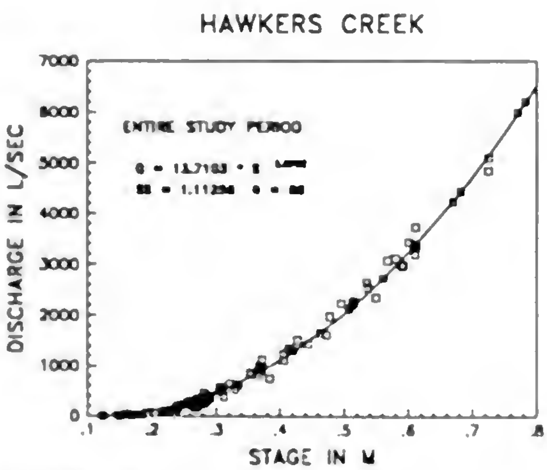

Figure 16: Stage-discharge curve and equation for Hawkers Creek at County Road 8 (HK1)

The ungauged portion of the Sturgeon Lake watershed covered 19,032 ha, or 3.99% of the total watershed area (Table 4). Discharge for the ungauged portion was prorated from the sum of the discharges of McLaren, Martin, Hawkers, Dunsford, Emily at Downeyville and Rutherford Creeks by

multiplying their combined discharges by the ratio of (unguaged/guaged area = .9385) The number of small watersheds and their diverse watershed characteristics combined to produce a discharge estimate which was thought to be representative of the unguaged area.

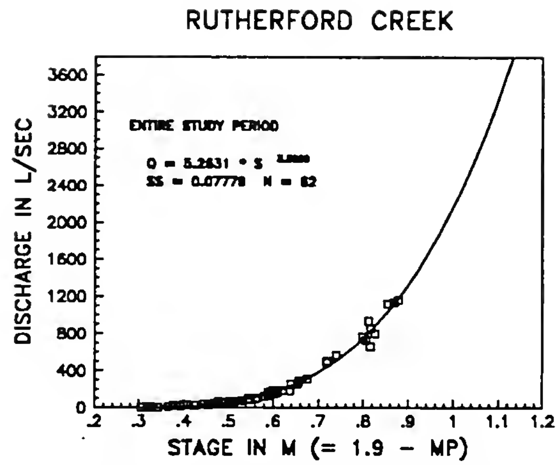

Figure 17: Stage-discharge curve and equation for Rutherford Creek at County Road 25 (RD1)

<u>Groundwater</u>

The till plains making up most of the Rice and Sturgeon Lakes study area are porous and thick enough to expect that groundwater recharge and discharge could contribute to the hydrology budget. Groundwater was not explicitly considered in hydrology budget calculations, however, due to the difficulty and expense involved in making accurate estimates over so large an area. Instead it was assumed that, on a drainage basin basis, aquifer recharge and discharge would balance over the long term and that any errors associated with discounting their contribution to the hydrologic budget would be insignificant.

<u>Outflow</u>

Discharge of Rice Lake to the Trent River at Hastings was determined by calculating flow downstream at Healey Falls and subtracting the incremental flow estimated for the area between Hastings and Healey Falls. Four components make up the total flow of the Trent River at Healey Falls (Figure 18). Flow through the Ontario Hydro powerhouse was measured. That portion of the flow which was diverted around the powerhouse was calculated from the depth of water flowing over the weir downstream of Healey Falls. Between May 15 and October 15, water was diverted through locks 15, 16 and 17 of the Trent-Severn Waterway. This flow was calculated from the record of number of lockages x lock volume to produce an average lockage volume of 0.56 $m^3.s^{-1}$ for the summer period. Finally, a volume of 0.6 $m^3.s^{-1}$ was estimated for leakage through valves and gates on the locks and added to the lockage volume to produce a volume of 1.16 $m^3.s^{-1}$ for lockage + leakage.

Incremental flow between Hastings and Healey Falls was estimated by prorating the daily discharge of the Ouse River (WSC, Station 02HK002) by the ratio of the incremental drainage area to the Ouse drainage area (22,000 ha/28,000 ha = 0.78). This estimate of flow was subtracted from the total daily discharge at Healey Falls to obtain daily outflow from Rice Lake.

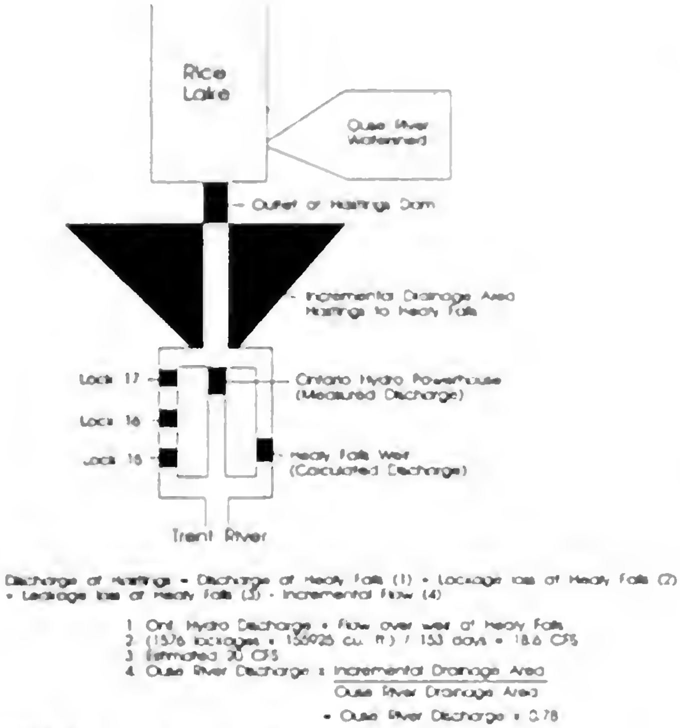

Figure 18: Schematic diagram of methods used by Parks-Canada to calculate daily discharge to the Trent River at the Rice Lake outlet at Hastings

Nine components made up the estimate of Sturgeon Lake discharge at the outlet in Bobcaygeon (Figure 19). The major flow through two, 15.2m wide radial gates in the Big Bob Channel was calculated by Parks Canada staff using gate opening rating curves for each of the radial gates. During the period October 1-December 7, 1988 the flow passed through the stoplog sluices of the Big Bob Channel dam instead of the radial gates. A standard contracted rectangular weir formula was used to calculate the daily discharge through the dam for this period. A total of 4.38 $m^3.s^{-1}$ was estimated as leakage and seepage through spillways, walls, dykes and sluiceways in the Big Bob and Little Bob Channels. Discharge through the Bobcaygeon Water Treatment Plant averaged 0.028 $m^3.s^{-1}$. Leakage through Lock 32 of the Trent-Severn Waterway was estimated as 0.142 $m^3.s^{-1}$ and lockage loss determined as the product of lock volume and number of daily lockages during the May 15 - October 15 navigation season.

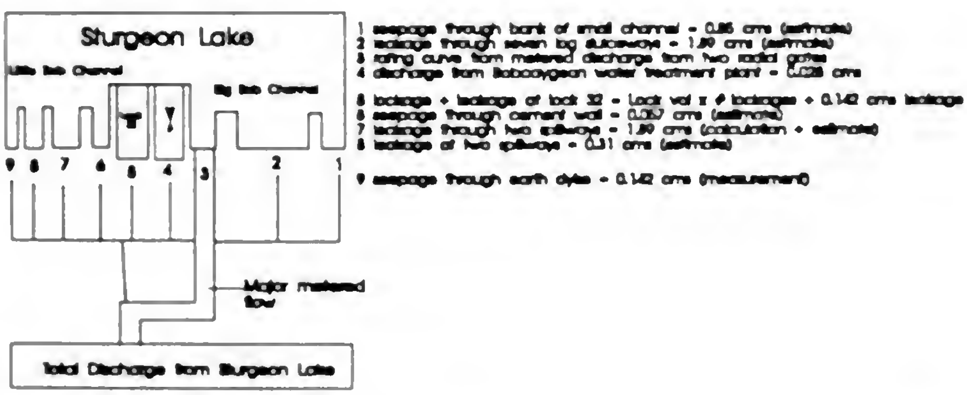

Figure 19: Schematic of method used by Parks Canada to calculate daily discharge of Sturgeon Lake at Bobcaygeon.

Net Evaporation

Net evaporation from the surface of each lake (evaporation loss - condensation gains) was calculated for the ice-free period as the residual term in the energy balance equation. Evaporation was assumed to be zero during the period of ice cover. Detailed methods for evaporation calculations are presented in Scheider et al. (1983) and Ontario Ministry of the Environment (1982). A summary of the technique is given here.

Heat exchange due to direct precipitation to the lake surface, runoff into and out of the lake and sediment loss was assumed to be negligible. The energy balance equation was thus simplified to:

$$R-S=LE+H$$

where: R = net radiation to the lake surface
S = change in heat storage in lake water
H = sensible heat exchange between water surface and atmosphere
LE = latent heat exchange between the water surface and the atmosphere where L = latent heat of vaporization (590 cal/gm)
and E = water vapour exchange

The Bowen ratio (B) (Bowen 1927) is used to separate the terms LE and H as follows:

B=H/LE, and is independently estimated as:

$$B=\frac{T_w-T_a}{e_w-e_a}$$

where T_w = surface water temperature
T_a = air temperature
e_w = saturation vapour pressure at T_w
e_a = saturation vapour pressure at T_a

therefore, the equation simplifies to:

$$LE=R-\frac{S}{(1+B)}$$

Data requirements to solve the heat balance equation and sources of each for the Rice and Sturgeon Lake Study are as follows:

Surface water temperature (T_w) - Measured biweekly during the ice-free period by staff of Central Region, MOE (see Hutchinson et al. 1993b).

Air Temperature (T_a) - Measured daily at Lindsay Frost and Peterborough -Trent meteorological stations and obtained from Atmospheric Environment Service of Environment Canada.

Saturation Vapour Pressure (e_w) - Obtained for T_w from standard tables.

Vapour Pressure (e_a) - Calculated for T_a from relative humidity measurements made at the Peterborough Airport meteorological station by AES.

Heat Storage in Lake (S) - Calculated from the mean temperature of each lake measured biweekly by Central Region staff. Rice and Sturgeon Lakes do not stratify and so mean temperature (all stations, all depths) was used as a reliable surrogate for the heat budget.

Net Radiation at Lake Surface (R) - Calculated as incoming short wave radiation (R_s) minus net long wave radiation loss from the lake (R_L).

R_S was measured at the Dorset Research Centre meteorological site as solar radiation in cal·cm^{-2}. The only alternative site was the Toronto Airport station of AES. The Dorset site was closer to the study area and so it was used.

R_L was calculated as a function of observed and maximum hours of sunlight and vapour pressure. Hours of bright sunshine were measured at the Lindsay Frost and Peterborough Trent meteorological stations by AES. Maximum possible hours of sunshine were calculated for the latitude of the Dorset Research Centre from standard tables.

Dates of formation and loss of ice cover were determined from records kept by local observers. Linear interpolation was used to calculate lake water temperatures on the first day of each month from biweekly sampling records so that evaporation could be calculated on a monthly basis. Monthly totals were calculated from smaller intervals, and these were summed to produce seasonal and annual totals.

Storage

Storage changes for each lake were calculated as the product of the difference in lake level on the first day of each month and the surface area of the lake. Daily lake levels were measured using float actuated instruments located at Harwood on Rice Lake and Sturgeon Point on Sturgeon Lake, and which were maintained by staff of the Trent-Severn Waterway, Parks Canada. Monthly storage volumes were summed to produce net seasonal and net annual changes in lake storage.

Hydrologic Characteristics

Residence time of water in each lake was calculated as lake volume/(outflow + storage) for each month of the study. Seasonal and average residence times were calculated from total volumes for the respective time periods, as opposed to three or twelve-month averages. All residence times were expressed in days. Areal runoff (m/yr) was calculated as total discharge/watershed area for each stream and watershed yield was calculated as areal runoff/depth of precipitation. Baseflow was calculated on monthly, seasonal and annual bases as the lowest observed flow for each time period for each stream.

Watershed areas for Cameron Lake (Sturgeon Lake inflow), the Sturgeon Lake outlet at Bobcaygeon, the Scugog and Otonabee Rivers and the Trent River outflow of Rice Lake were obtained from The Trent-Severn Waterway. The watershed areas for the Indian and Ouse Rivers were obtained from The Otonabee Region Conservation Authority and The Water Survey of Canada respectively. Watershed areas of all remaining streams were determined by digitizing from the height of land delineated on 1: 50,000 topographic maps. Land-use characteristics for small streams were digitized from the same topographic maps and those for the Indian and Ouse Rivers were digitized from Figure 4.1 in Otonabee Region Conservation Authority (1983). No land-use characterization was attempted for the major inflows and outflows.

Step-wise multiple regression was used to examine for any relationship between water yield and land-use characteristics. Land use was expressed as percent of each of the 11 small watersheds occupied by agricultural area, dry forest, wet forest, urban area, lake, or marshland. These percentages were used as independent variables in a regression with yield and regressions were considered significant at $p < 0.05$.

RESULTS AND DISCUSSION

Rice Lake

Hydrographs of daily discharge for all Rice Lake tributaries are plotted in six month segments for the entire three year study period in Figures 20 to 25.

All streams showed a typical pattern of highest flow during the March-April spring freshet, lowest flow in the July-August period and increasing flow in the October-November period. Instantaneous field discharge measurements (spot Q) plotted over top of the hydrographs (Figures 20 to 25) indicate that the continuous stage records, combined with the rating curves for each stream, produced reliable records of discharge. The exception to this was the summer period for the Indian River, where spot discharges were consistently lower than daily flow estimates. This may be related to the daily schedule of operation for the Hope Mill and dam upstream.

Histograms of mean daily discharge frequency for each stream are shown in Figures 26 to 31. The relatively even distribution of discharge for the Otonabee and Trent Rivers reflect their size, the presence of large lakes upstream and numerous control structures designed to maintain consistent flows through the Trent-Severn Waterway. Size and the presence of upstream controls appear to maintain a more even distribution of flow in the Indian and Ouse River, compared to the Bewdley North and South tributaries. Bewdley South in particular exhibited a flashy response. Flow in the stream was <100 L/s for nearly 80% of the study period, yet reached extreme values of 3340 L/s (Figure 20, Table 3). By comparison, 90% of the measured flows in Bewdley North were <100 L/s, but extremes only reached a maximum of 392 L/s (Figure 21, Table 3). Wetlands above and below the monitoring site broadened the hydrograph of Bewdley North, so that its response to increasing and decreasing runoff was slower than in the predominantly agricultural watershed of Bewdley South.

Monthly and seasonal discharge volumes and watershed characteristics are summarized in Tables 7 to 13 and Figures 32 to 37. Annual summaries are given in Table 3 and Figure 38. Total discharge figures confirm that the March, April, May spring period produced maximum runoff volume and that the Bewdley South watershed showed the greatest between-month variation in relative flow. Total discharge was more evenly distributed across all months in the other watersheds.

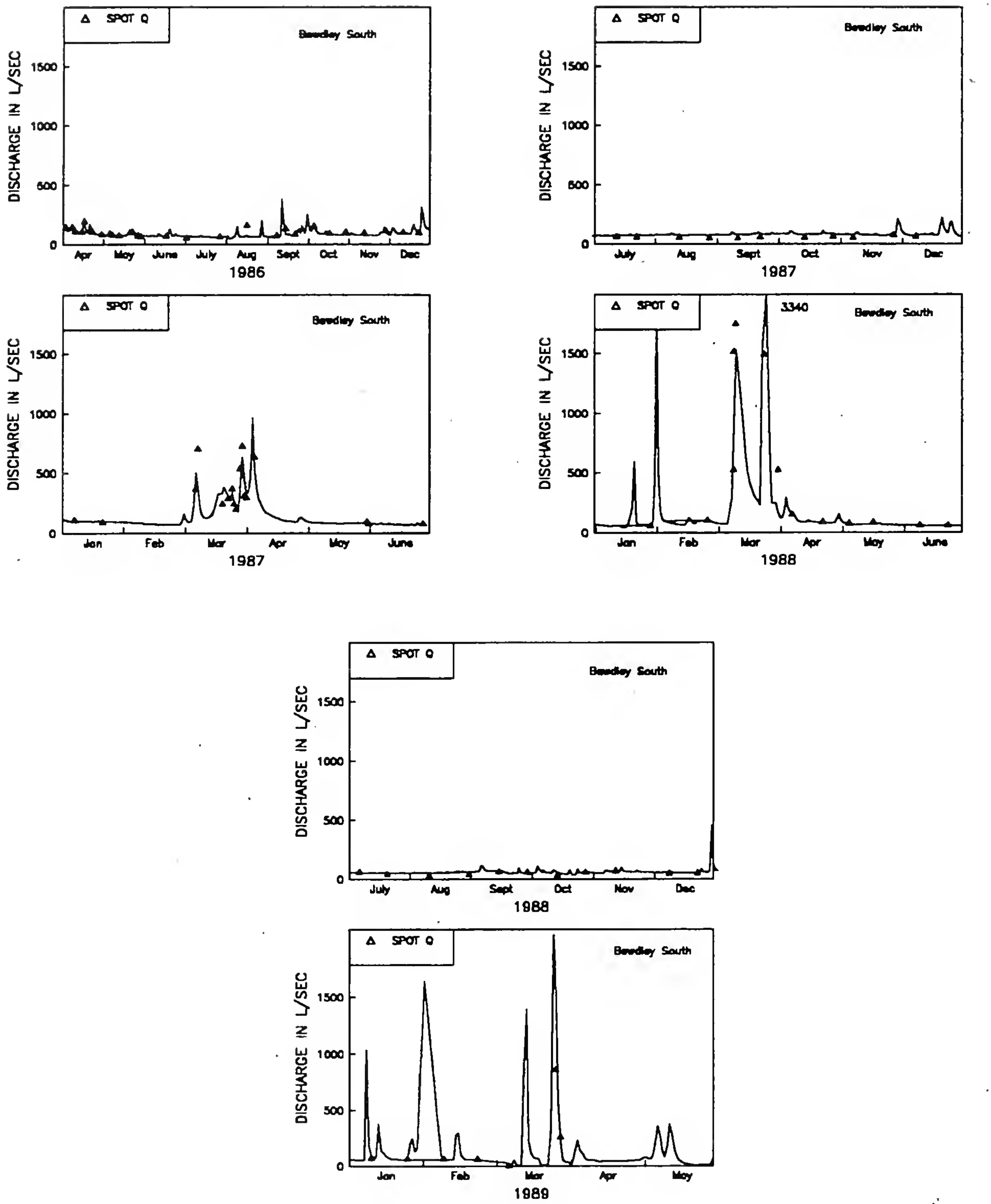

Figure 20: Daily discharge ($L \cdot s^{-1}$) for Bewdley South, April 1, 1986 to May 31, 1989. Spot Q = instantaneous discharge.

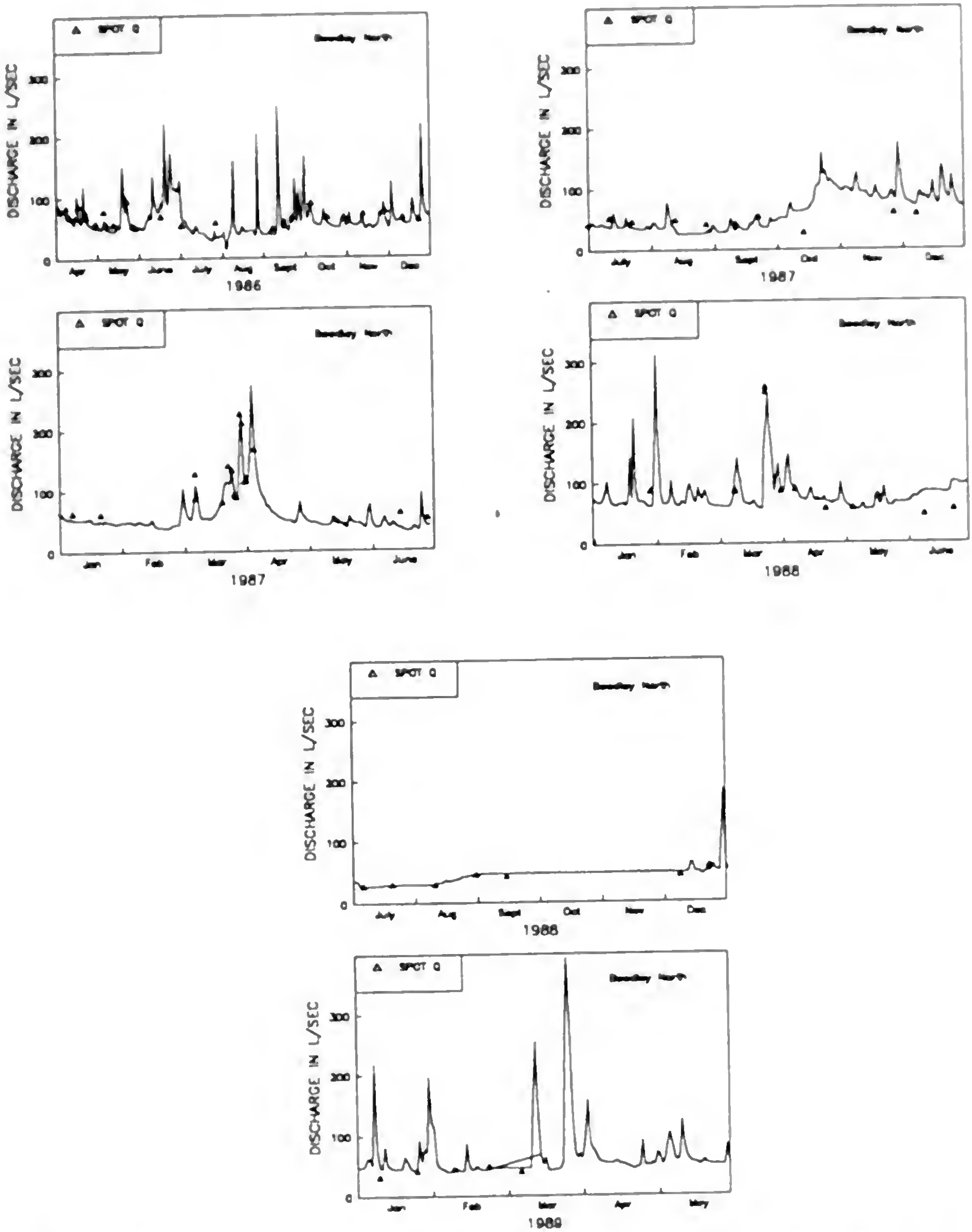

Figure 21: Daily discharge ($L{\cdot}s^{-1}$) for Bewdley North, April 1, 1986 to May 31, 1989. Spot Q = instantaneous discharge.

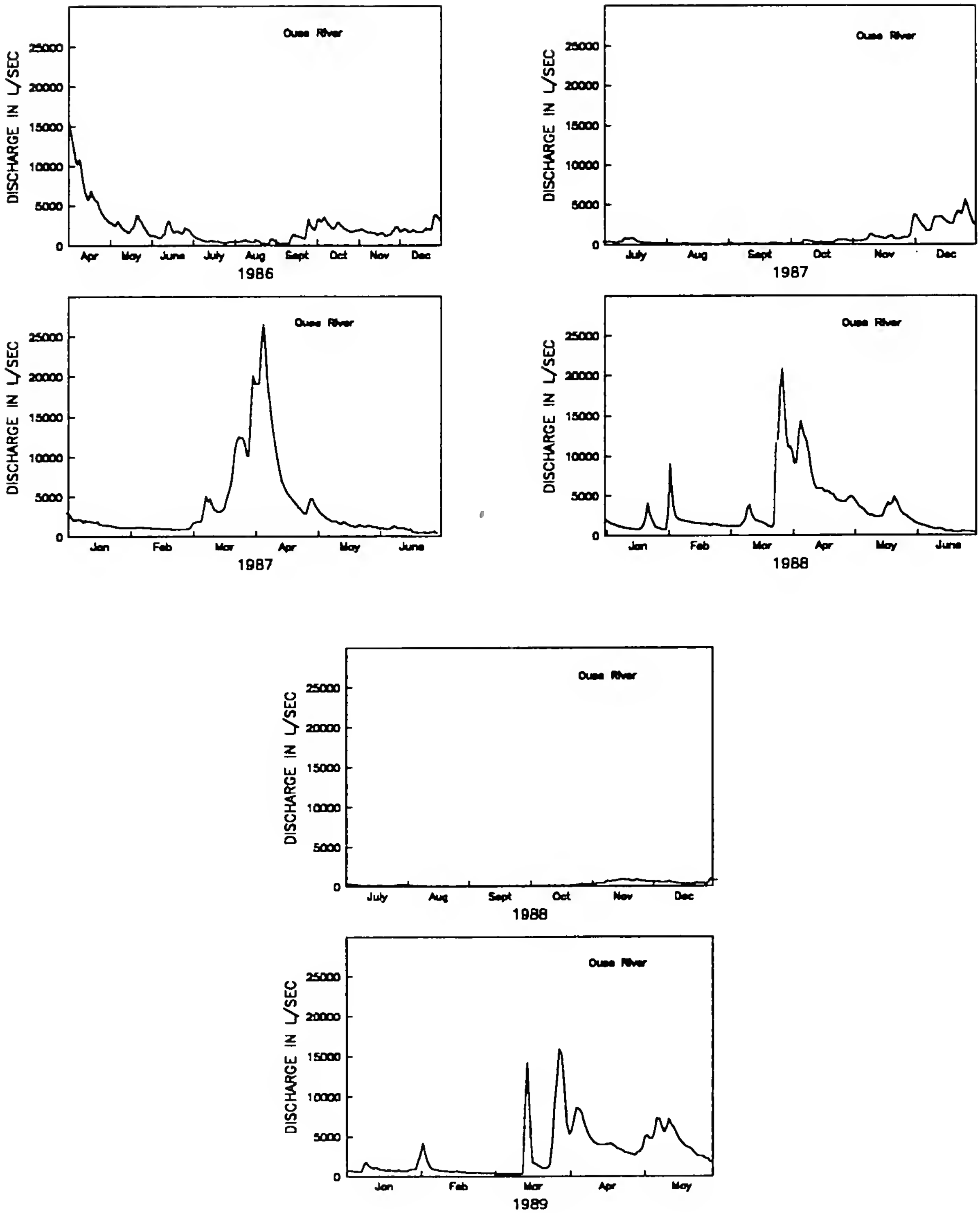

Figure 22: Daily discharge ($L \cdot s^{-1}$) for the Ouse River, April 1, 1986 to May 31, 1989. Spot Q = instantaneous discharge.

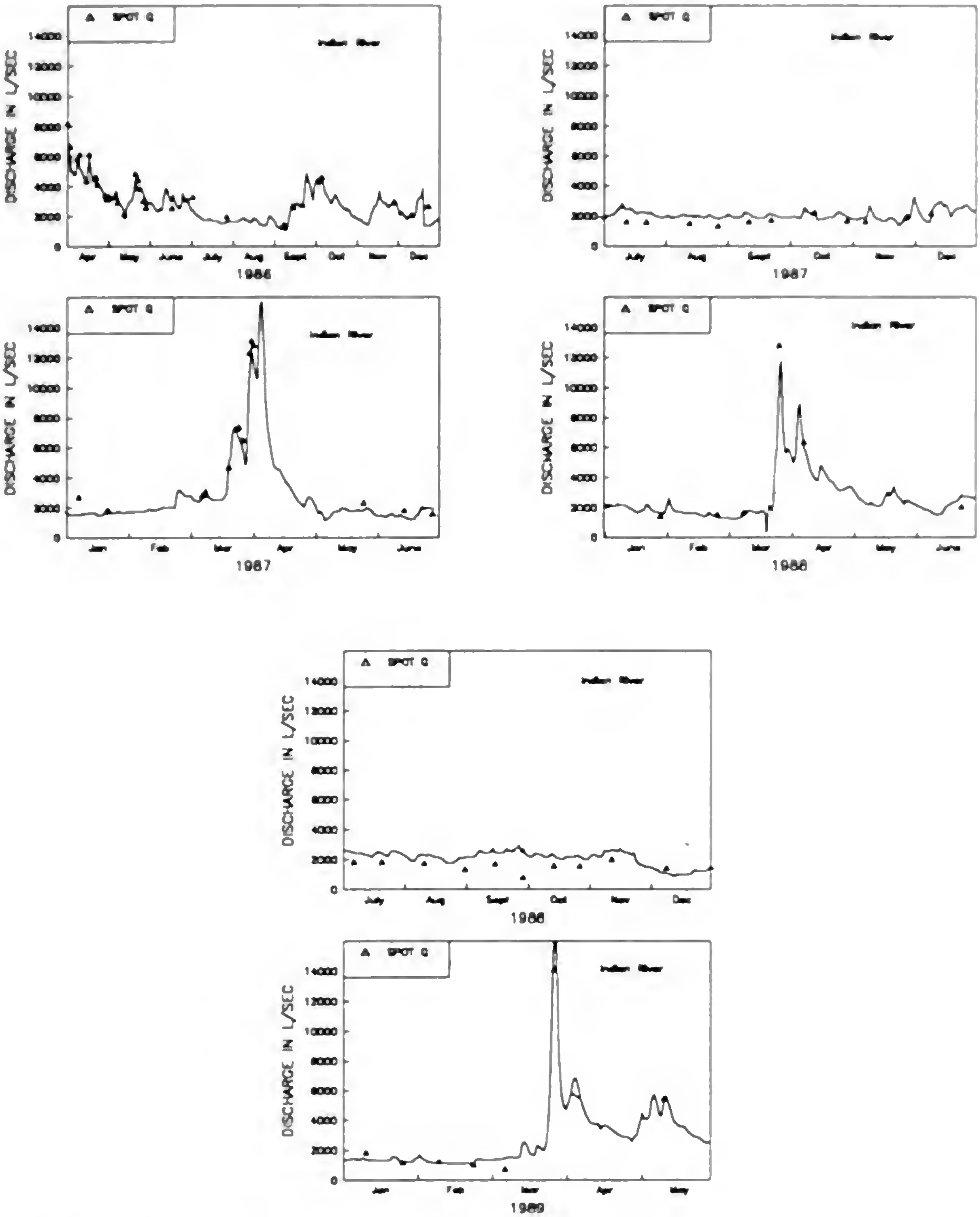

Figure 23: Daily discharge ($L \cdot s^{-1}$) for the Indian River, April 1, 1986 to May 31, 1989. Spot Q = instantaneous discharge.

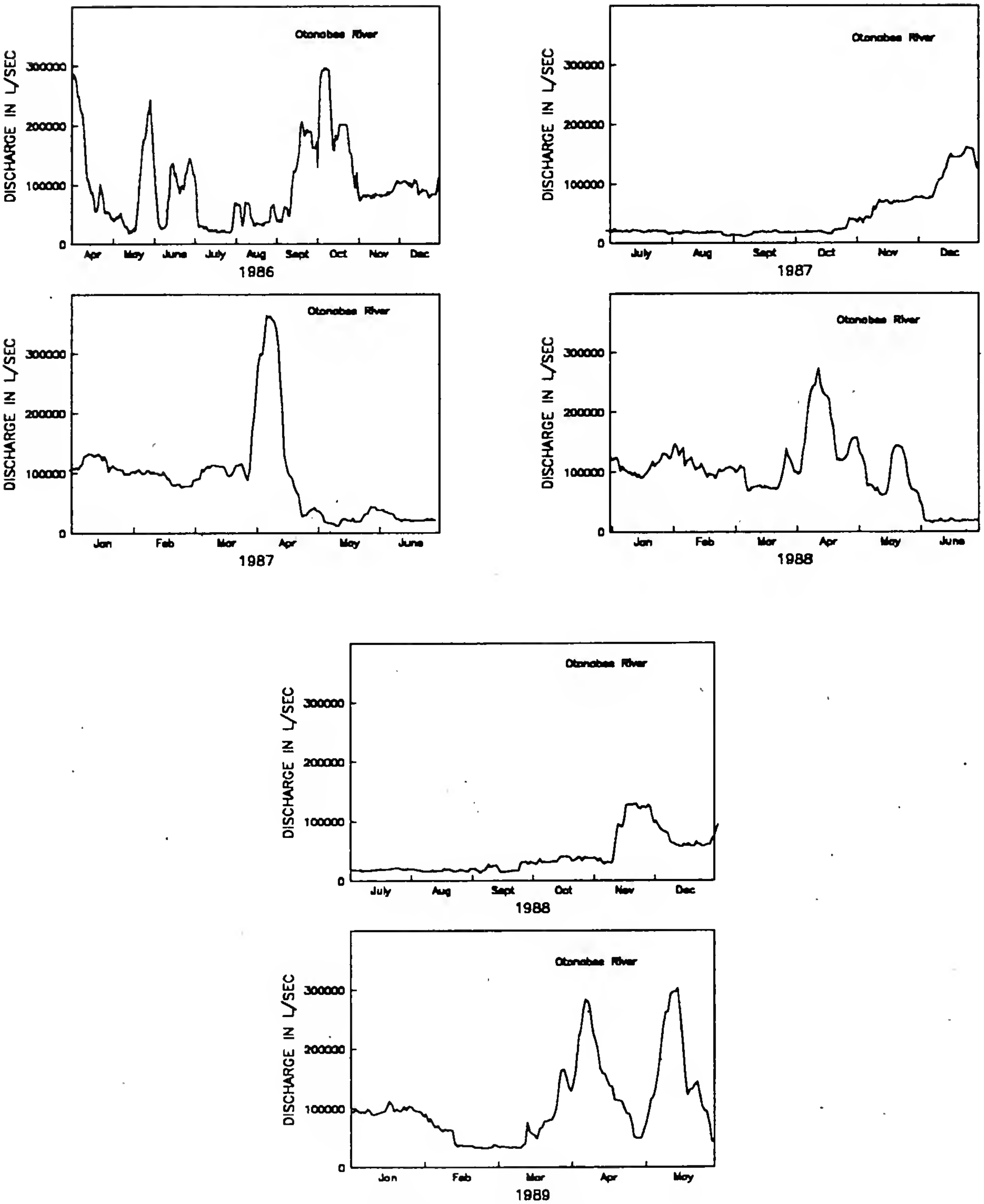

Figure 24: Daily discharge ($L{\cdot}s^{-1}$) for the Otonabee River for April 1, 1986 to May 31, 1989. Spot Q = instantaneous discharge.

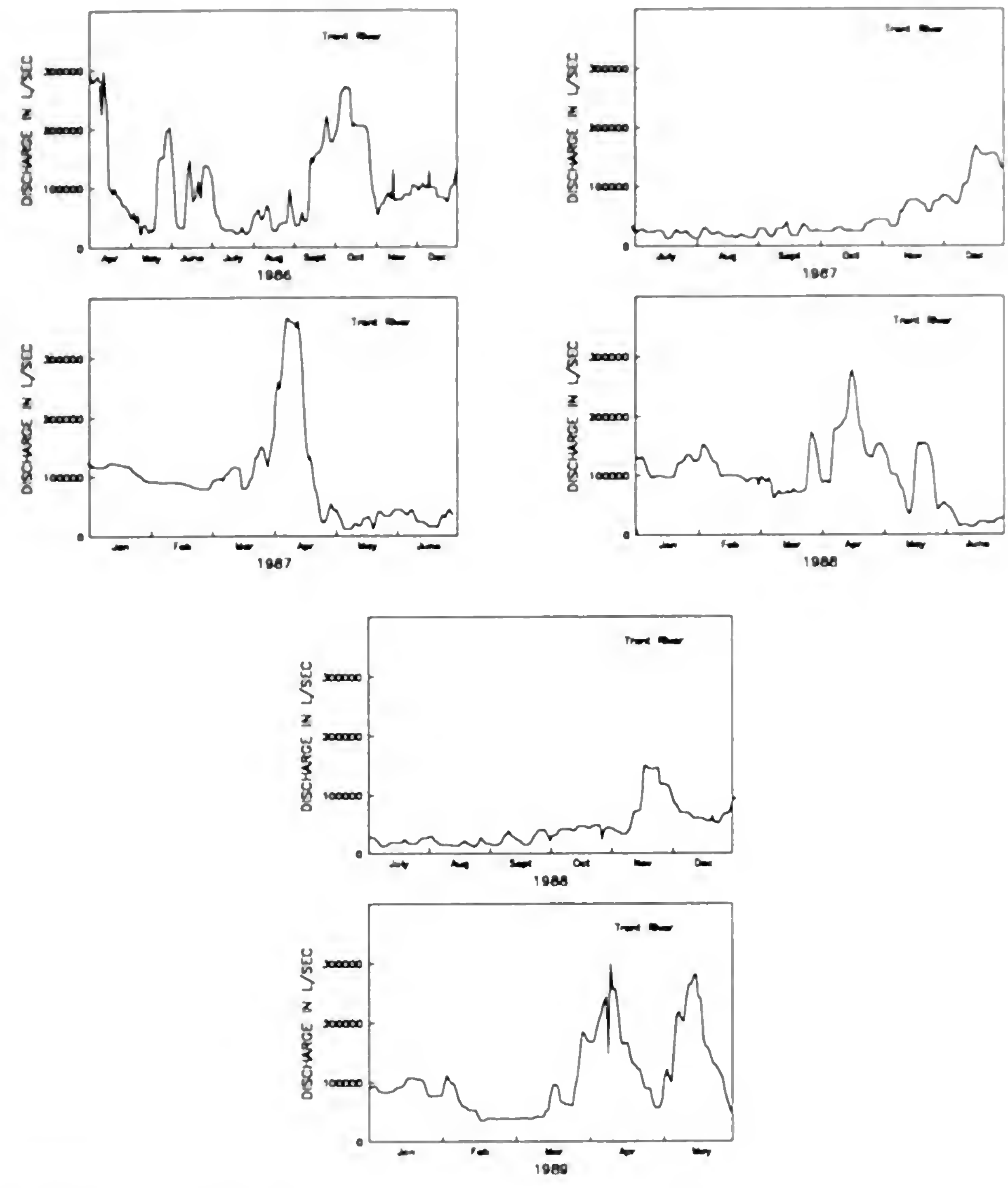

Figure 25: Daily discharge (L·s^{-1}) for the outlet of Rice Lake, April 1, 1986 to May 31, 1989. Spot Q = instantaneous discharge.

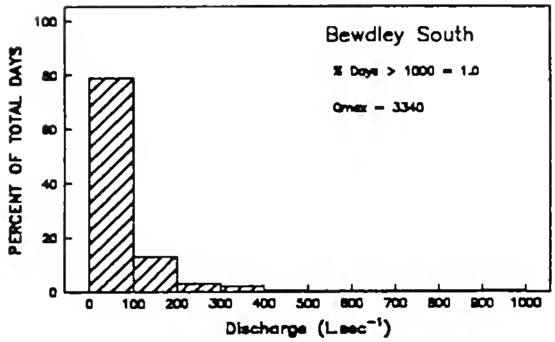

Figure 26: Histogram of daily discharge frequencies for Bewdley South

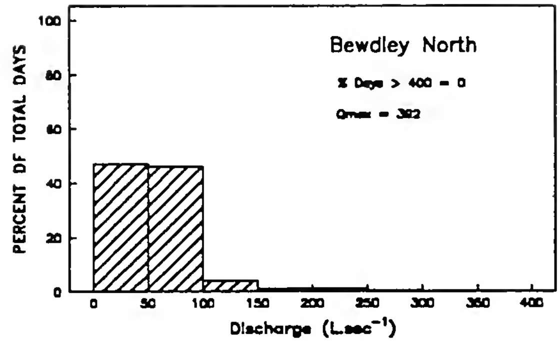

Figure 27: Histogram of daily discharge frequencies for Bewdley North

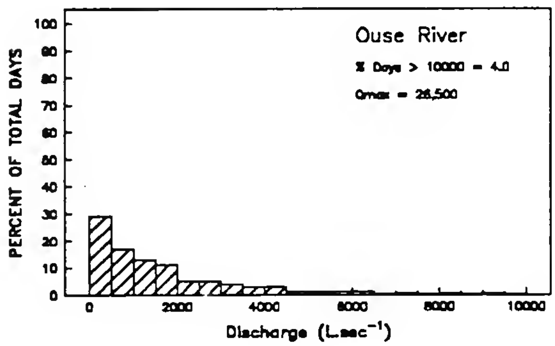

Figure 28: Histogram of daily discharge frequencies for the Ouse River

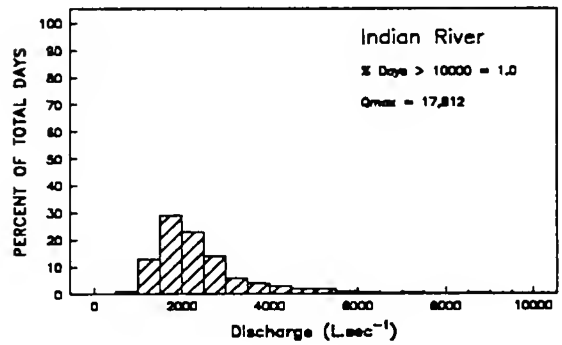

Figure 29: Histogram of daily discharge frequencies for the Indian River

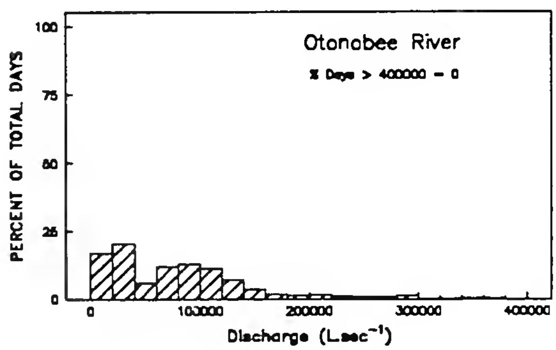

Figure 30: Histogram of daily discharge frequencies for the Otonabee River

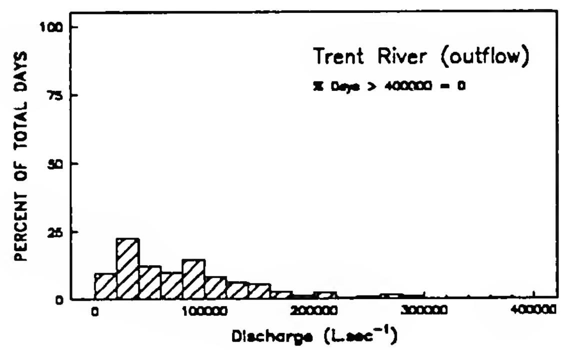

Figure 31: Histogram of daily discharge frequencies for the Trent River

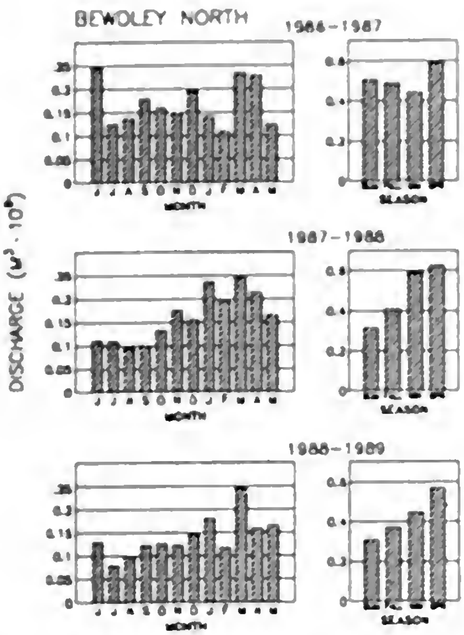

Figure 32: Mean monthly and seasonal discharge for Bewdley North

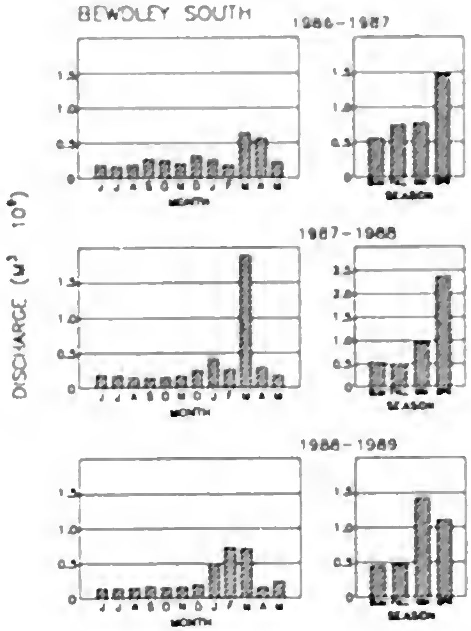

Figure 33: Mean monthly and seasonal discharge for Bewdley South

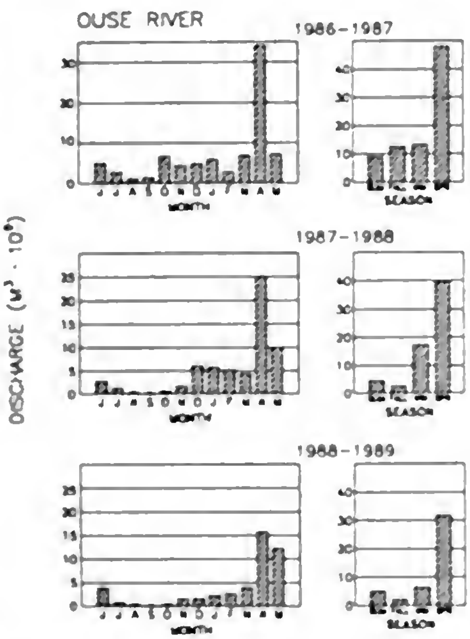

Figure 34: Mean monthly and seasonal discharge for the Ouse River

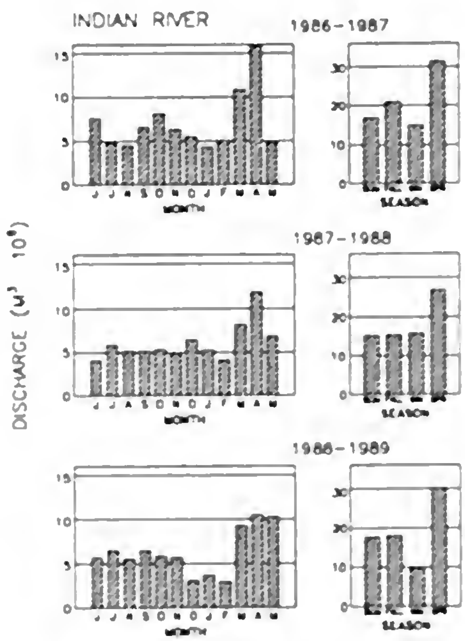

Figure 35: Mean monthly and seasonal discharge for the Indian River

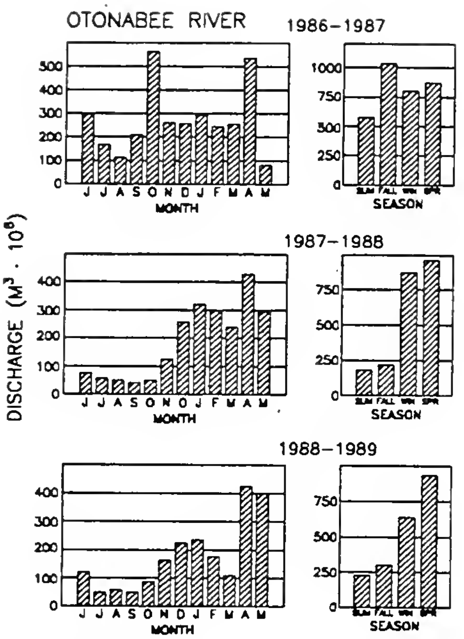

Figure 36: Mean monthly and seasonal discharge for the Otonabee River

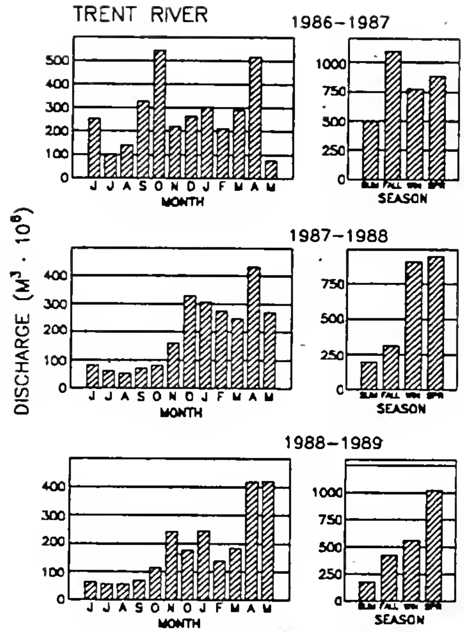

Figure 37: Mean monthly and seasonal discharge for the Trent River

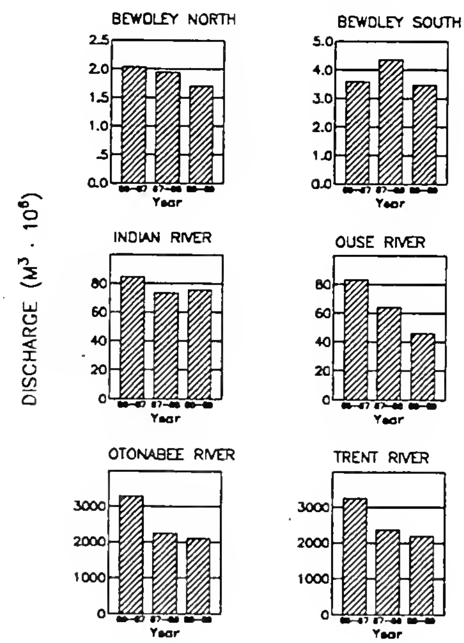

Figure 38: Total annual discharge for all subwatersheds

Values of areal runoff (total discharge/watershed area) for the entire Rice Lake watershed, as measured at the outflow at Hastings, ranged from 0.24-0.36 m/yr in each of the study years (Table 13, Appendix 1). This compares well with the long-term value of 0.3 m/yr obtained from the Hydrological Atlas of Canada (Table 2). The lowest values for areal runoff were those measured at the Bewdley South tributary and estimated for the ungauged portion of the watershed; these ranged from 0.12-0.20 m/yr.

Values for percentage yield from each watershed (areal runoff/depth of precipitation) ranged from 20.5% to 68.6% on an annual basis. The lowest yields (i.e. 1%, Ouse River, September 1988, Table 9, Appendix 1) corresponded to the late summer and early autumn months when dry land retained most of the rainfall. By contrast, yields for the spring freshet frequently exceeded 100%, indicating release of snowpack water. The highest yield of 325.8% for March 1988 (Table 8, Appendix 1), was recorded at Bewdley South, again suggesting that watershed characteristics produced a different response there than on other tributaries.

Annual evaporation from the surface of Rice Lake ranged from 0.56 to 0.67 m/yr in each of the study years (Table 14, Appendix 1, Figure 39). No evaporation was calculated for the period of ice cover and maximum evaporation of 0.37 to 0.43 m was calculated for the summer season. Annual precipitation ranged from 0.686 m in 1988-89 to 0.821 m for 1987-88 (Table 14) compared to the 30 year average of 0.798 m (Table 2). Autumn was the wettest season in all three study years (Figure 40) and winter the driest.

Monthly changes in the level of Rice Lake ranged from a drop of 13 cm in October 1986 to a rise of 21 cm in March of 1989; all referenced to an average level of 186 m above sea level (MASL, Table 15, Figure 41, 42). The net changes in level of Rice Lake were -8.0 cm, 0 cm and 2.0 cm in 1986-87, 1987-88 and 1988-89 respectively. Storage contributions to the Rice Lake hydrology budget were thus much more important on a monthly or a seasonal basis then they were on an annual basis.

The hydrology budgets for Rice Lake are summarized in Tables 16 to 20 and Figures 43 to 48. Individual supply and loss terms are presented on a monthly and seasonal basis in Tables 16 to 19 and the annual budget figures are given in Table 20. Overall, the input and output terms balanced to within 3.5 to 8.7% in each of the three years of the study. The annual hydrologic balance was negative when expressed as (Output-Input) in all three years, indicating either an overestimate of inflow terms or an underestimate of loss terms.

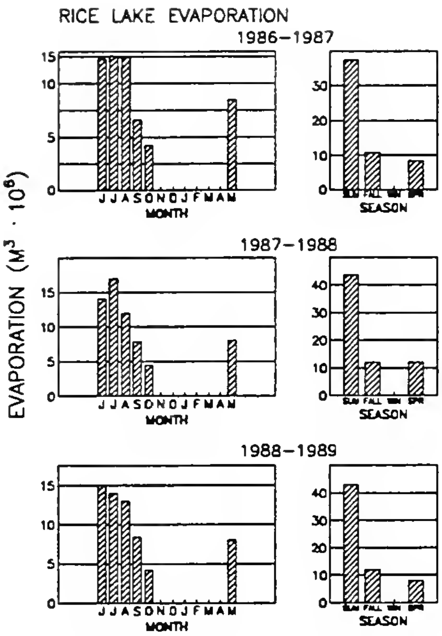

Figure 39: Monthly, seasonal and annual contributions of evaporation to the Rice Lake hydrology budget

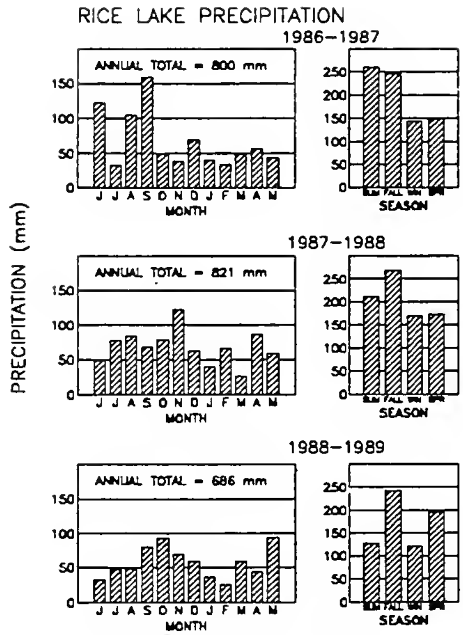

Figure 40: Monthly, seasonal and annual precipitation totals for Rice Lake

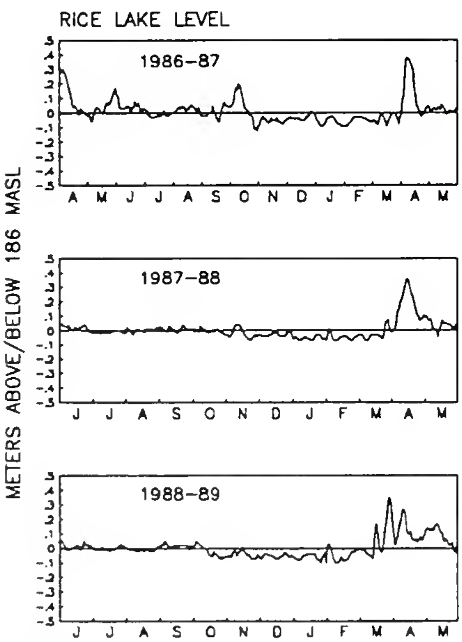

Figure 41: Record of daily levels of Rice Lake recorded at Harwood.

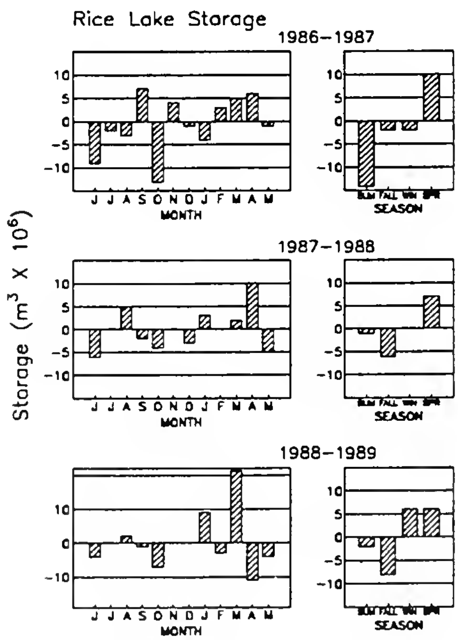

Figure 42: Monthly, seasonal and annual changes in storage for Rice Lake

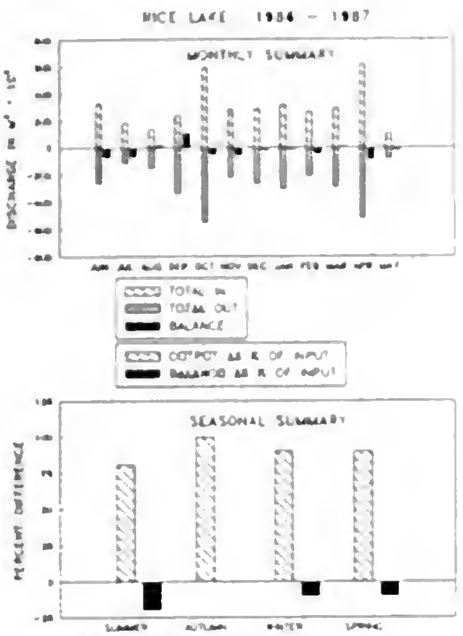

Figure 43: Monthly and seasonal balance of the Rice Lake hydrology budget ,1986-87.

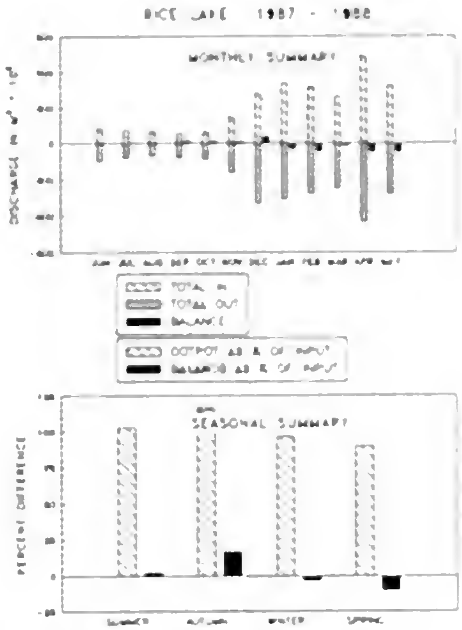

Figure 44: Monthly and seasonal balance of the Rice Lake hydrology budget for 1987-88

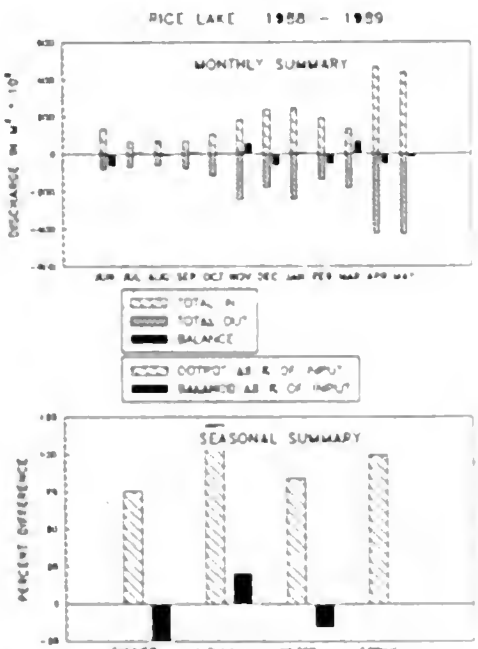

Figure 45: Monthly and seasonal balance for the Rice Lake hydrology budget for 1988-89

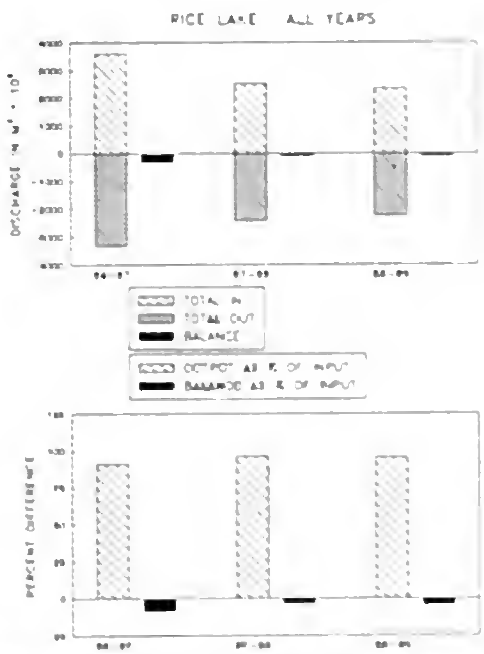

Figure 46: Annual balance of the Rice Lake hydrology budget for the hydrologic years 1987-87, 1987-88, 1988-89

The source of error is most likely to lie in estimates for the two major tributaries. The annual residual balance of the hydrology budget was approximately 10% of the annual flow of either of the Trent or the Otonabee Rivers. A small error in their estimates would therefore have had the greatest impact on the balance. By contrast, the residual balance term was 2-150 times greater than the contribution from storage changes, evaporation, or runoff from the minor tributaries and 1-4 times greater than contributions from the Indian and Ouse Rivers, and the ungauged portion of the watershed. Major adjustments in discharge estimates from these sources would be required to balance the hydrologic budget.

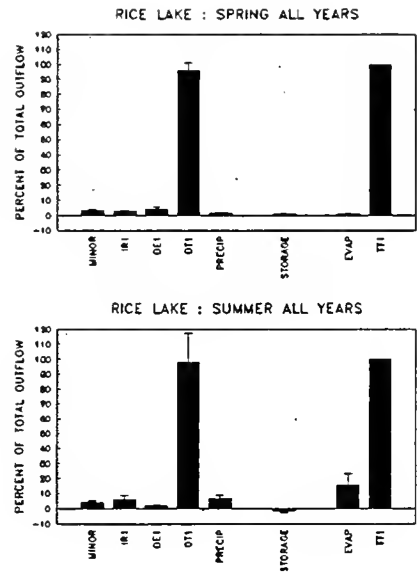

Figure 47: Seasonal averages for terms of the spring and summer Rice Lake hydrology budget for 1986-87, 1987-88, 1988-89

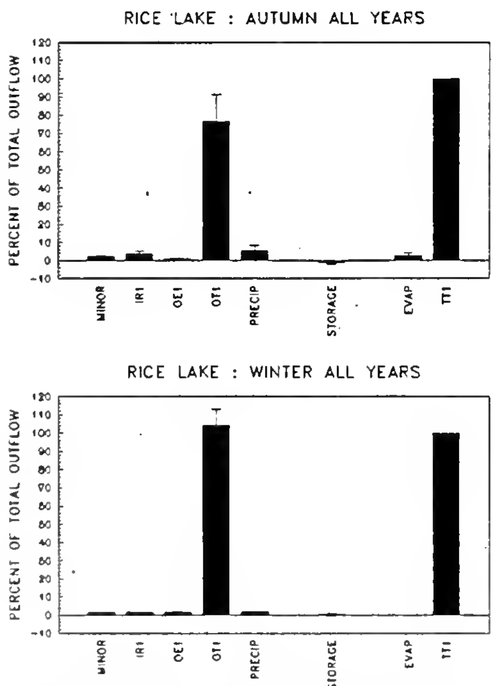

Figure 48: Seasonal averages for terms of the autumn and winter Rice Lake hydrology budget.

Over all three years, balance was poorest in the summer season (-15.5%). A positive balance (inflow < outflow) was only achieved in the autumns of 1987-88 and 1988-89and the summer of 1987. In the autumn of 1986, summer and winter of 1987 and spring of 1989, the budget was essentially balanced (error < 4% Table 19, Appendix 1). Spring was the season with the smallest relative error (7%) in the hydrology balance. September was the only month in which outflow exceeded total inflow in each of the three study years.

Figures 47 and 48 show that, regardless of season or year, the Rice Lake hydrology budget was dominated by the Otonabee River inflow and the Trent River outflow. The Otonabee River contributed 80-90% of the total inflow and the other tributaries could be ignored without affecting the accuracy of the hydrology balance.

Residence time for water in Rice Lake (volume/outflow + storage) ranged from a minimum time of 13.6 days in October 1986 to a maximum of 126 days in August 1988 (Table 21, Appendix 1). Figure 49 shows that residence time was lowest in April of all three years and highest in August, except for year 1 when the highest residence time was in May. The average residence time for Rice Lake over the course of the study ranged from 26.5 days in year 1 to 39 days in year 3.

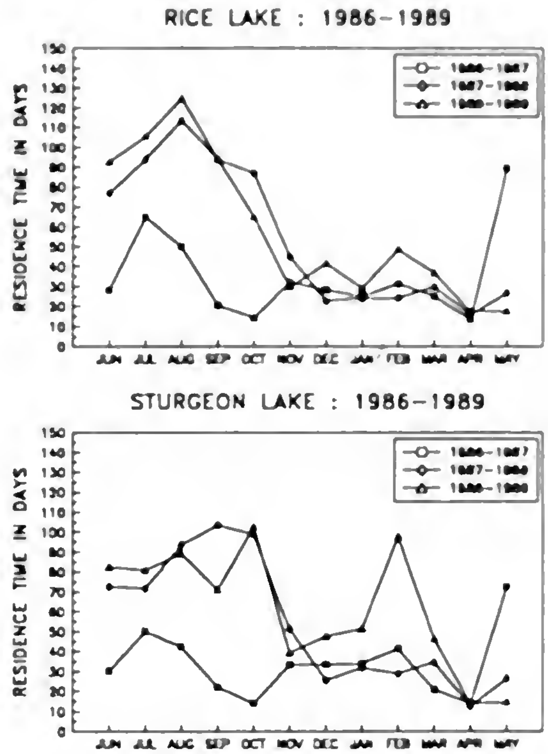

Figure 49: Monthly residence times in days for Rice and Sturgeon Lakes for the period 1986-89.

<u>Sturgeon Lake</u>

The stage-discharge relationships for the monitored streams on the Sturgeon Lake hydrology network are illustrated in Figures 12 to 17 and the equations summarized in Table 6. The Emily Creek at Downeyville tributary was the only creek on the Rice-Sturgeon network that responded to the summer 1988 drought with a different stage discharge relationship (Figure 13). During this period the rating was essentially a straight line relationship over the bottom of the hydrograph and measured discharges were 5 to 65 L/s. The equations for the remainder of the study had exponents of >1.5 which resulted in standard exponential rating curves. No rating curve is illustrated for the mouth of Emily Creek, as discharge was prorated from the Dunsford Creek and Emily at Downeyville tributaries.

Hydrographs of daily discharge for all Sturgeon Lake tributaries are plotted in six month segments in Figures 50 to 58. As before, those portions of the hydrograph which were estimated are plotted as dotted lines to distinguish them from the measured portions. All hydrographs followed a clear seasonal pattern of high discharge during March-April, low summer flow and increased discharge in response to autumn rains.

Measured instantaneous discharges show that reliable records of flow were obtained for each stream. The greatest error between measured and estimated flows was observed for the Scugog River (Figure 56) indicating the difficulty of estimating flow for that tributary. The Scugog River also showed less distinction of flow between seasons suggesting that it responded as much to control structures on Lake Scugog as it did to seasonality of precipitation.

Histograms of daily discharge frequencies for each stream are shown in Figures 59 to 68. Monthly, seasonal and annual discharge volumes are given in Figures 69 to 79. As with the Rice Lake watershed, histograms show the least variation between monthly and seasonal discharges for the controlled inflow and outflow at Fenelon Falls and Bobcaygeon respectively. The remaining tributaries showed the expected pattern of high flows in spring and autumn and low summer flow. Summer flows were lowest in the 1987-88 and 1988-89 study years. The minor tributaries; McLaren, Martin, Hawkers, Rutherford and Dunsford Creeks, were similar in discharge characteristics and did not show the extremes in response observed in the Bewdley South tributary to Rice Lake.

Values of areal runoff for the entire Sturgeon Lake watershed, as measured at the outlet at Bobcaygeon, ranged from 0.291 to 0.431 m/yr in each of the three study years (Table 22, Appendix 1). These values are greater than those measured for Rice Lake, and likely reflect the higher proportion of Precambrian Shield in the Sturgeon Lake watershed, where shallow soils produce greater runoff potential. This is further suggested by even higher areal runoff (0.39 - 0.46 m/yr) at the inflow at Fenelon Falls (Table 23, Appendix 1). McLaren, Martin, Hawkers and Dunsford Creeks appear to drain similar watersheds as annual runoff for these creeks ranged from 0.22-0.52 m/yr (Tables 24,25,27,29, Appendix 1), compared to 0.13 - 0.29 m/yr for the remaining tributaries (Tables 26,28,31 Appendix 1). Baseflow in the Sturgeon Lake tributaries was less than that for Rice Lake tributaries. Zero discharge was recorded at Hawkers, Rutherford, McLaren and Dunsford Creeks in 1987-88 and 1988-89 (Table 4). In contrast, minimum recorded flow for the Rice Lake watershed was 8 L/s (Table 3).

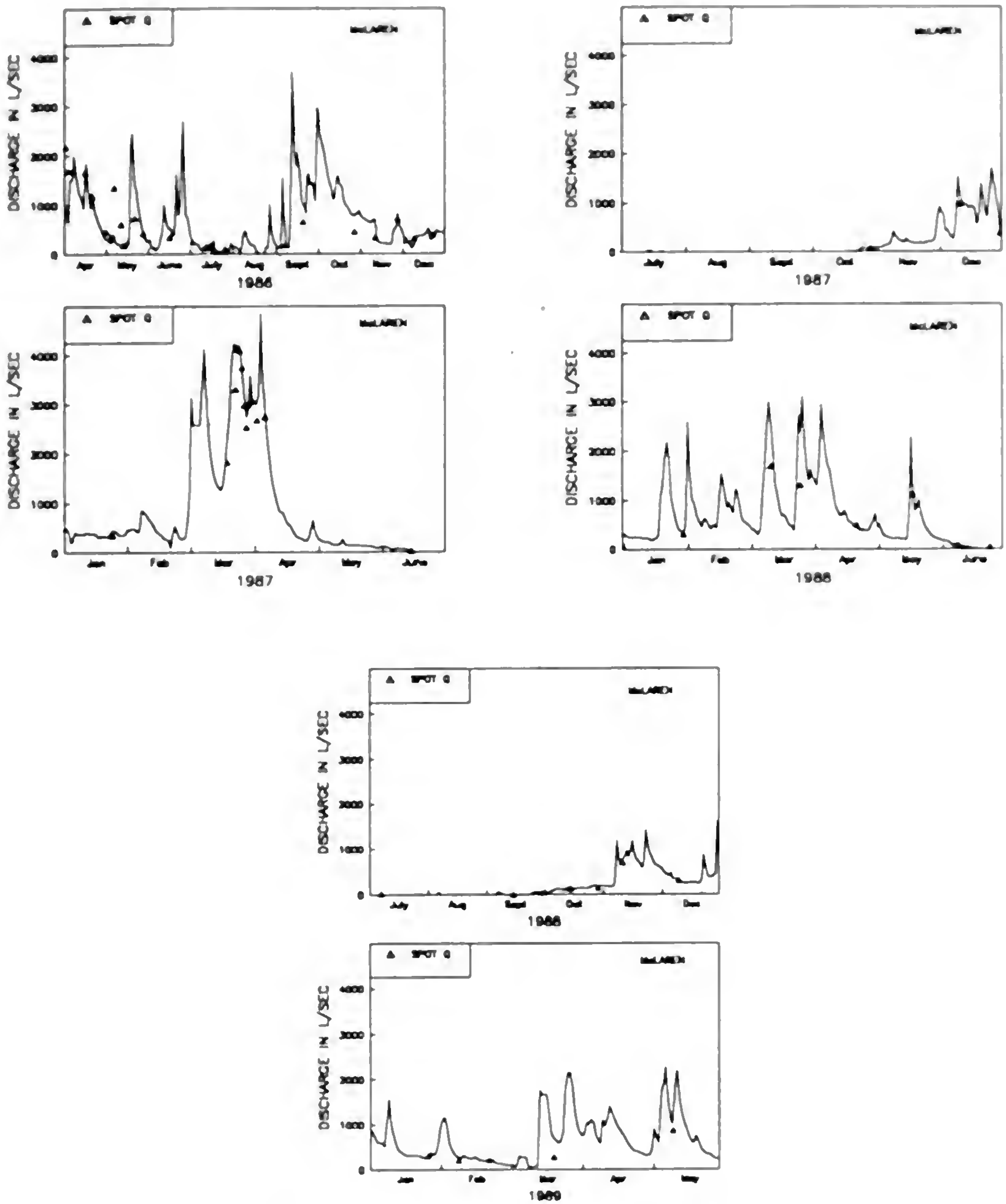

Figure 50. Daily discharge ($L \cdot s^{-1}$) for McLaren Creek , 1986 to 1989. Spot Q = instantaneous discharge.

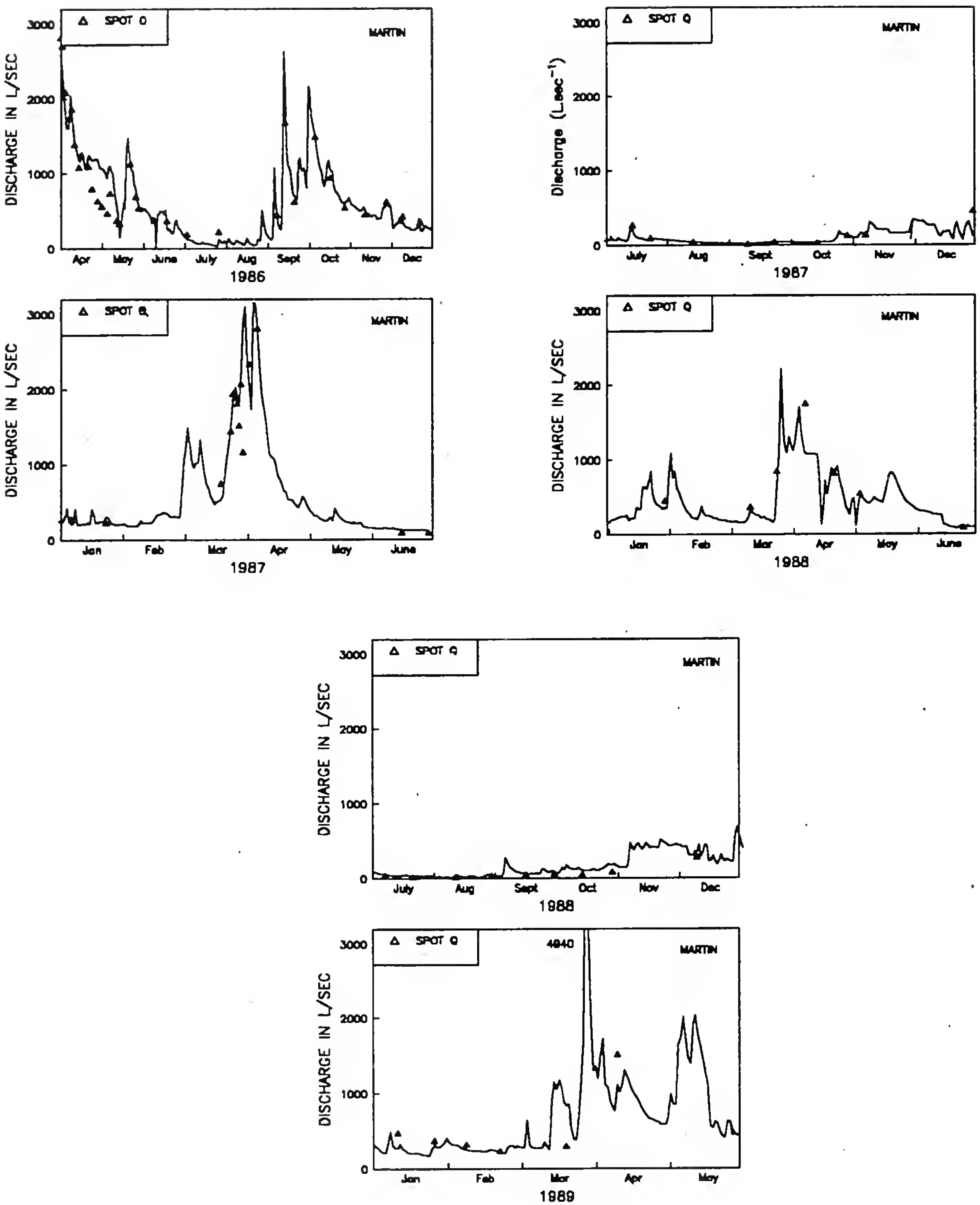

Figure 51. Daily discharge (L·s⁻¹) for Martin Creek, 1986 to 1989. Spot Q= instantaneous discharge

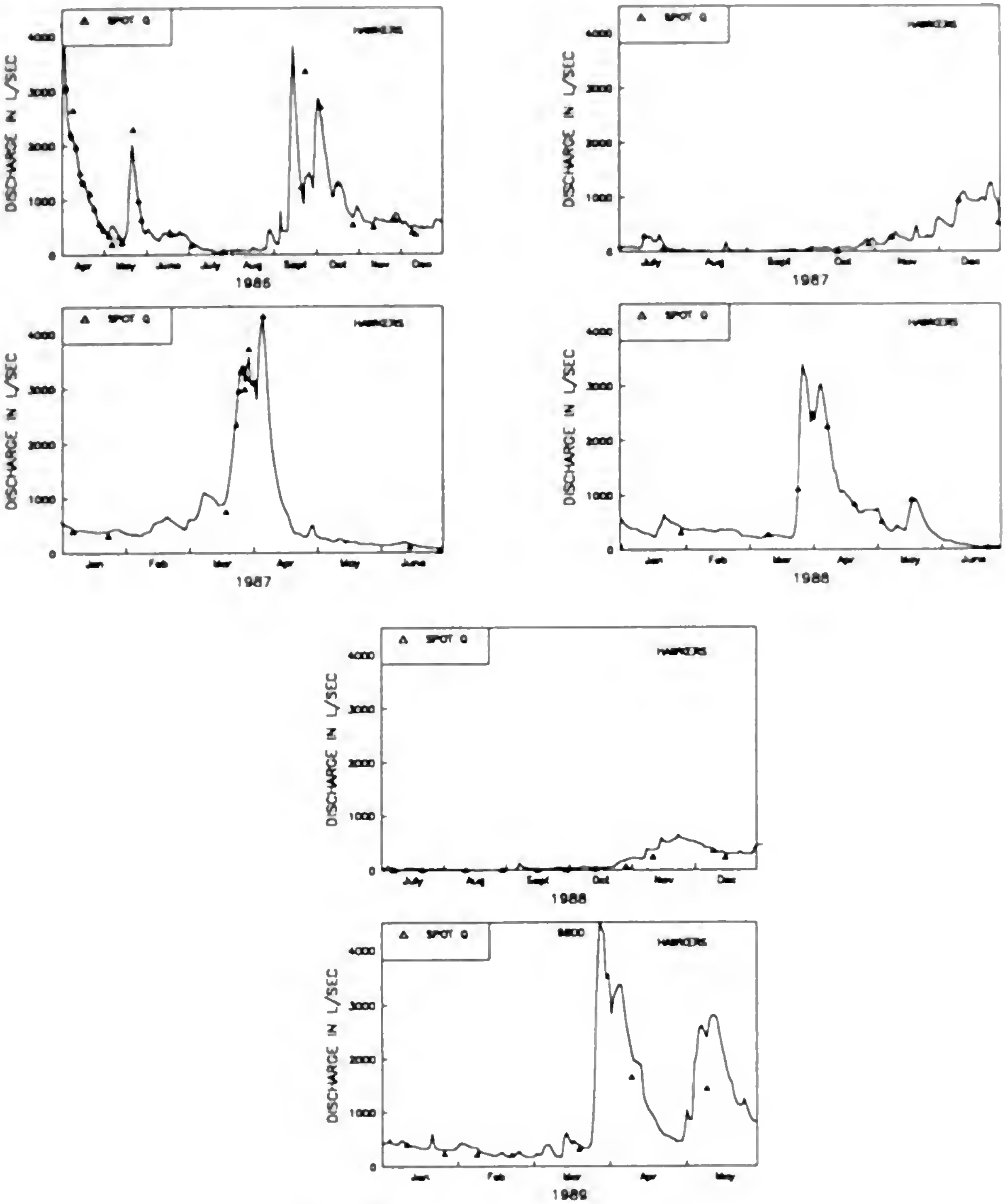

Figure 52. Daily discharge ($L \cdot s^{-1}$) for Hawkers Creek, 1986 to 1989. Spot Q = instantaneous discharge.

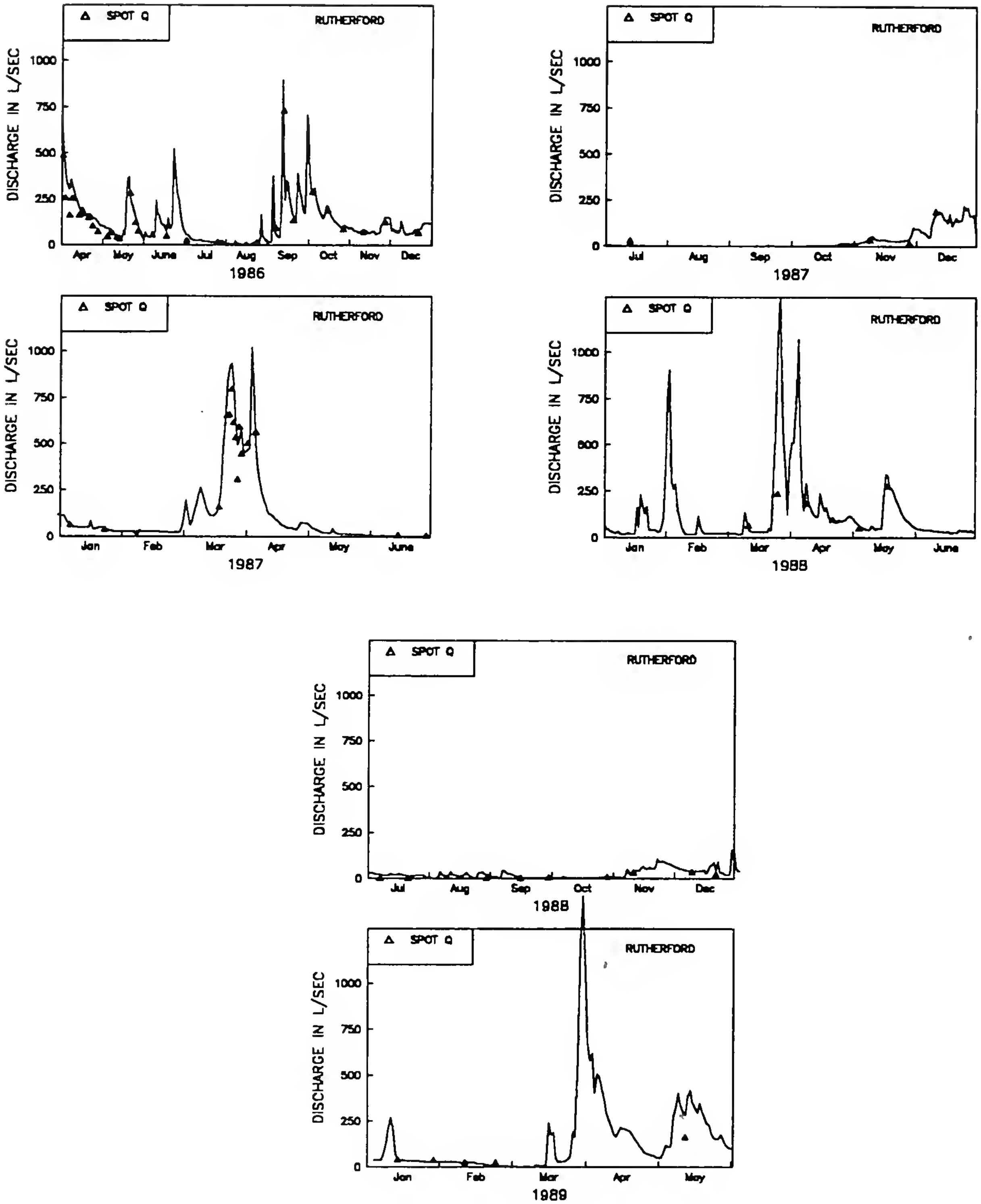

Figure 53. Daily discharge ($L \cdot s^{-1}$) for Rutherford Creek, 1986 to 1989. Spot Q = instantaneous discharge.

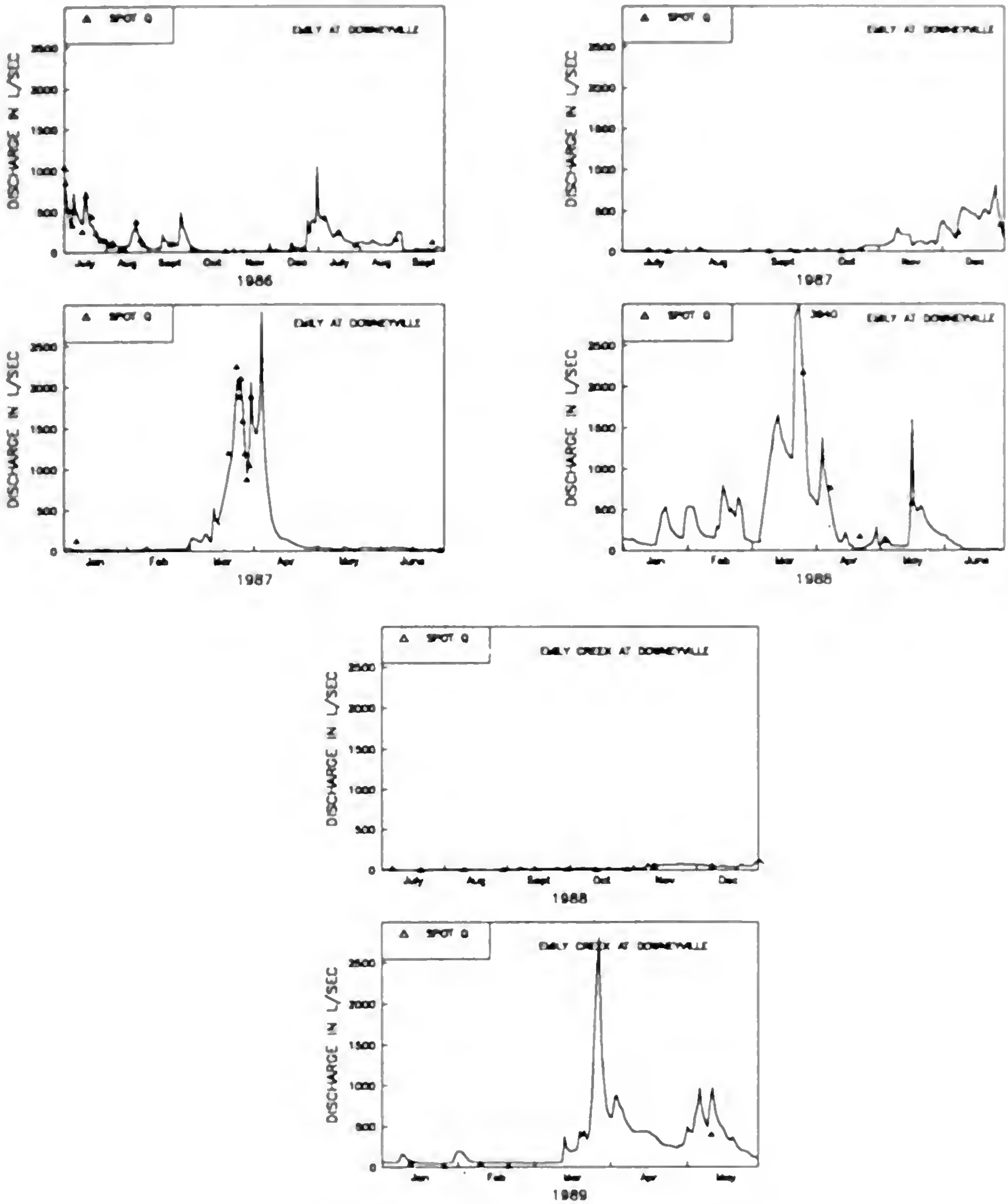

Figure 54. Daily discharge ($L \cdot s^{-1}$) for Emily Creek at Downeyville, 1986 to 1989. Spot Q = instantaneous discharge.

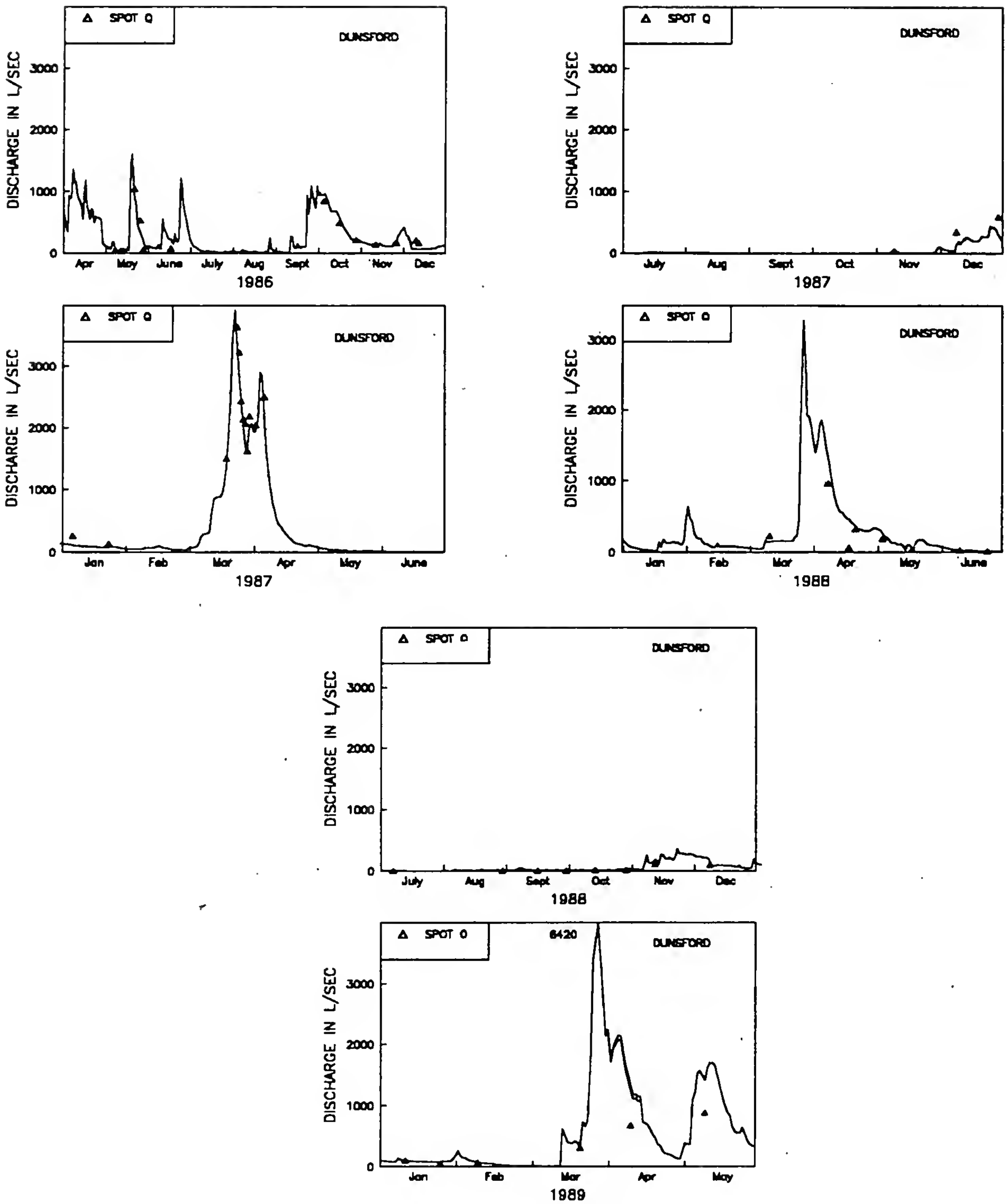

Figure 55. Daily discharge ($L \cdot s^{-1}$) for Dunsford Creek, 1986 to 1989. Spot Q = instantaneous discharge.

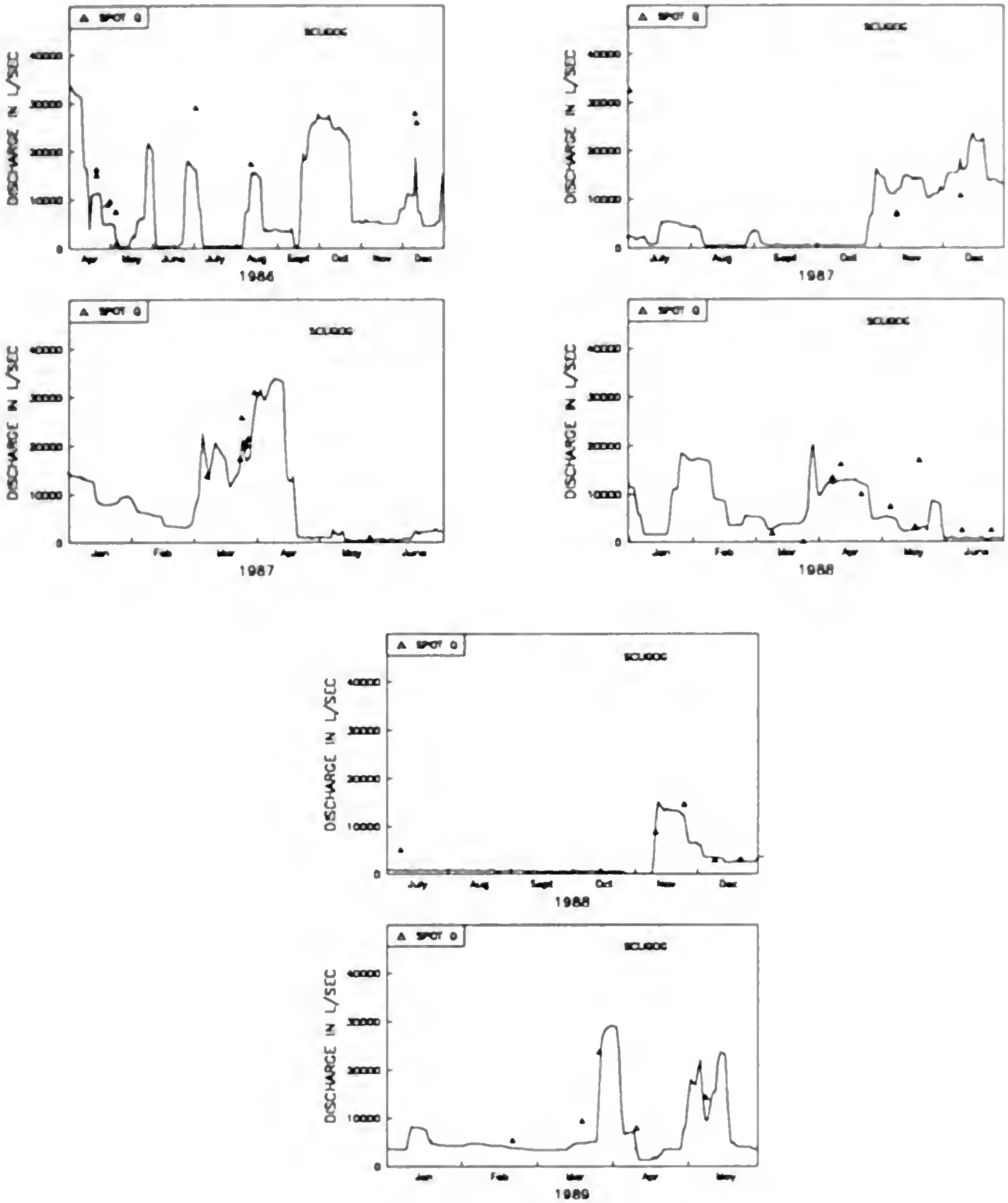

Figure 56. Daily discharge ($L \cdot s^{-1}$) for the Scugog River, 1986 to 1989. Spot Q = instantaneous discharge.

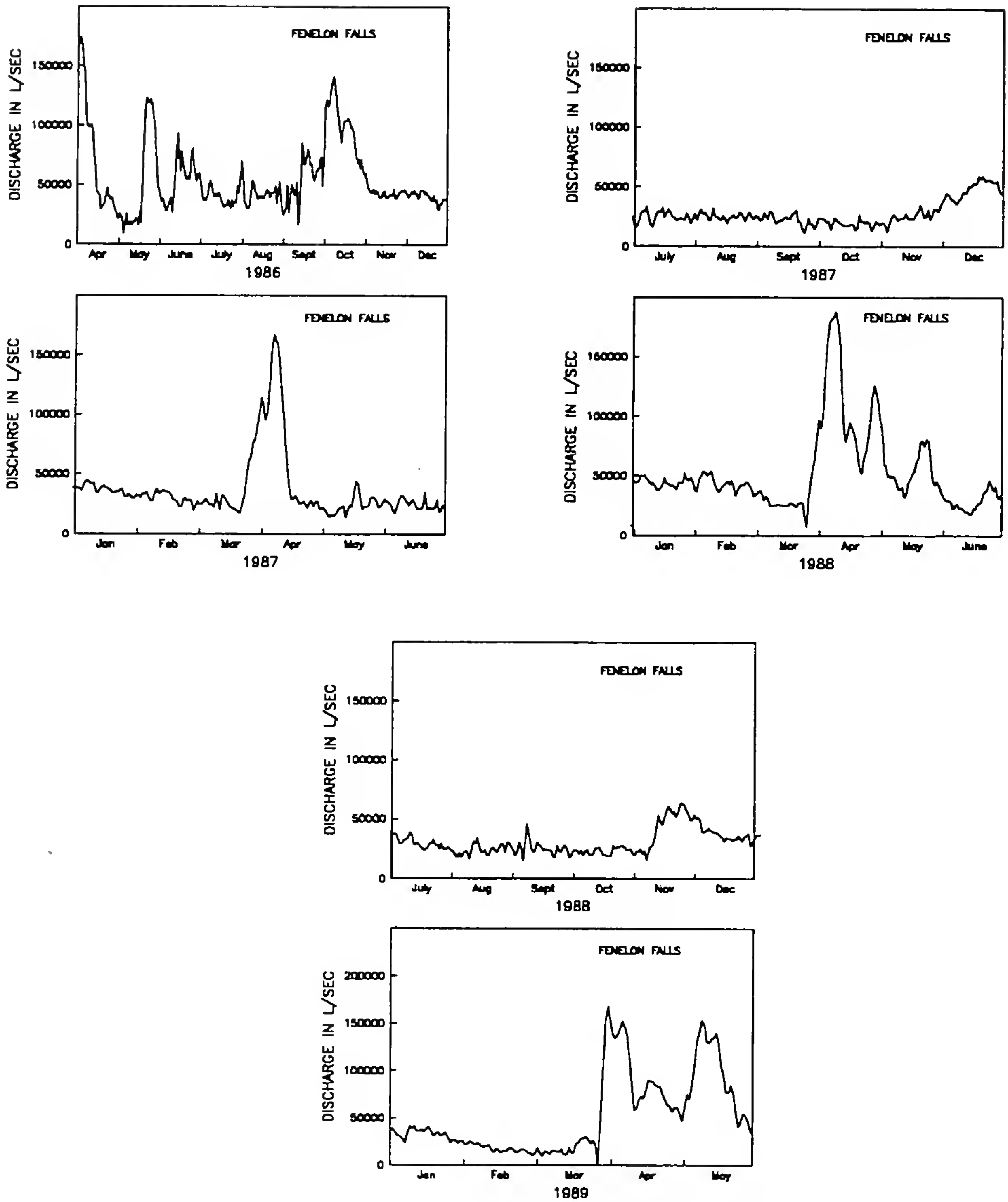

Figure 57. Daily discharge ($L \cdot s^{-1}$) for Fenelon Falls , 1986 to 1989. Spot Q = instantaneous discharge.

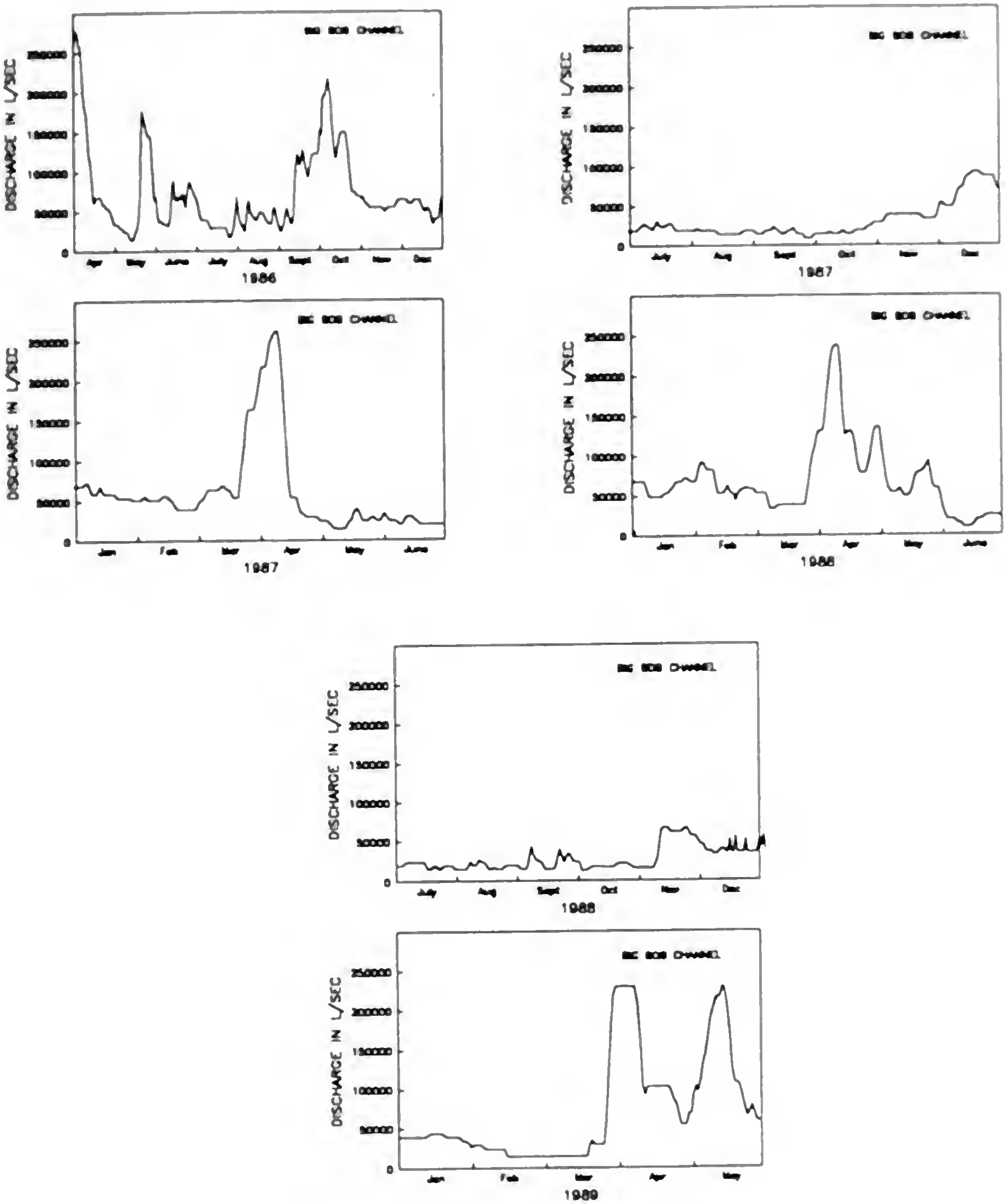

Figure 58. Daily discharge ($L \cdot s^{-1}$) for Sturgeon Lake at Bobcaygeon, 1986 to 1989. Spot Q = instantaneous discharge.

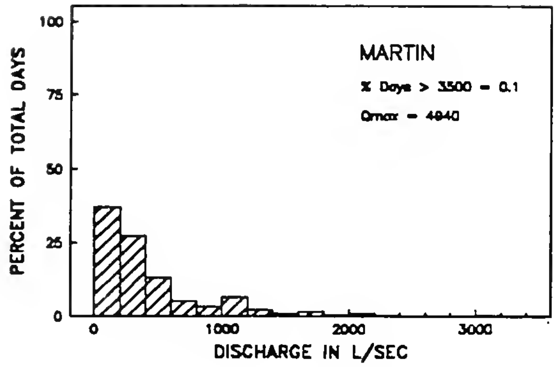

Figure 59. Histogram of daily discharge frequencies for Martin Creek

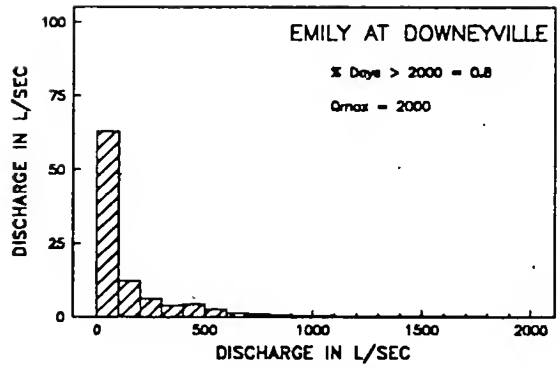

Figure 60. Histogram of daily discharge frequencies for Emily Creek at Downeyville

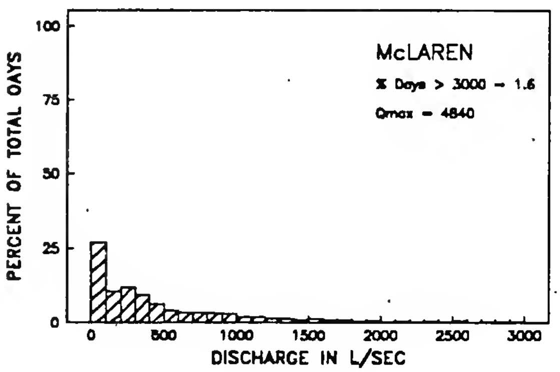

Figure 61. Histogram of daily discharge frequencies for McLaren Creek

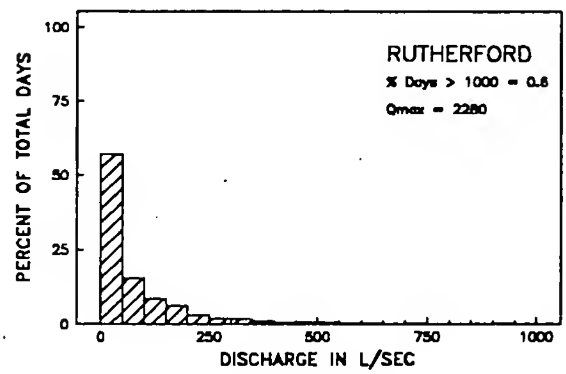

Figure 62. Histogram of daily discharge frequencies for Rutherford Creek .

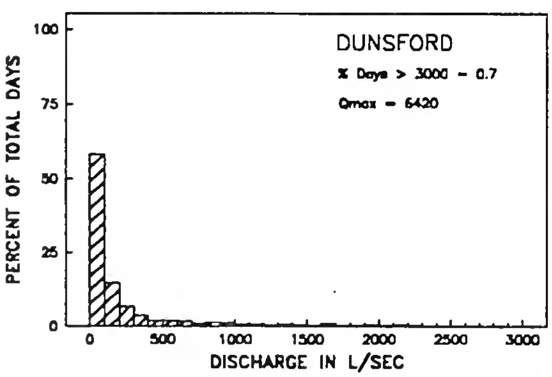

Figure 63. Histogram of daily discharge frequencies for Dunsford Creek.

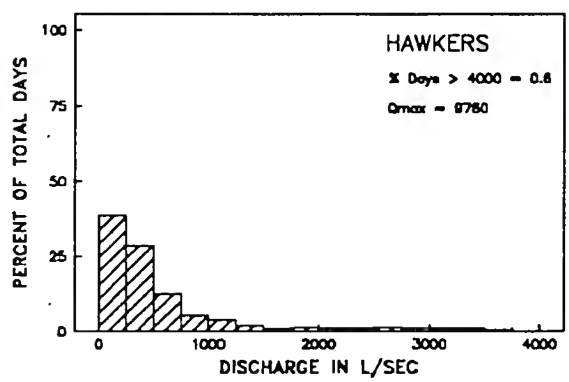

Figure 64. Histogram of daily discharge frequencies for Hawkers Creek.

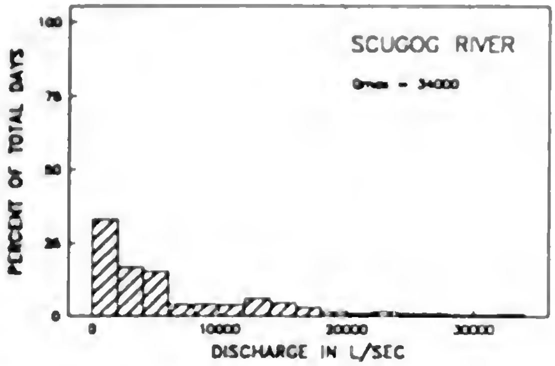

Figure 65. Histogram of daily discharge frequencies for the Scugog River.

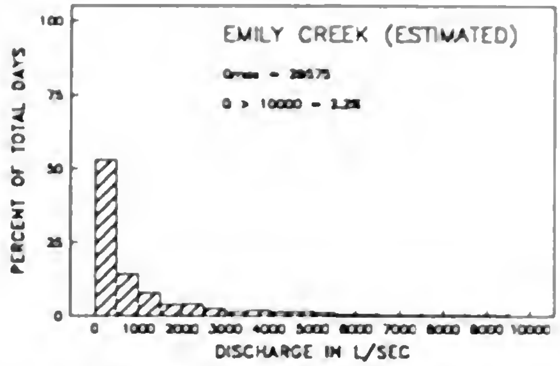

Figure 66. Histogram of daily discharge frequencies estimated for Emily Creek at Sturgeon Lake.

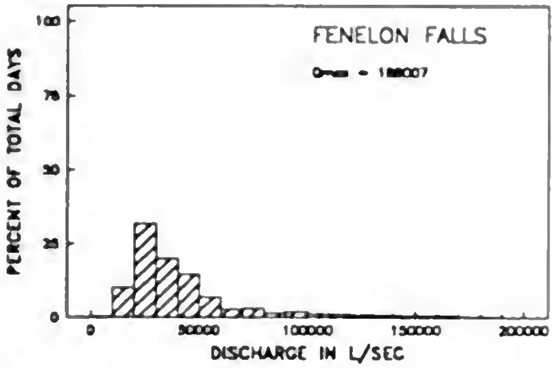

Figure 67. Histogram of daily discharge frequencies for the outlet of Cameron Lake to Sturgeon Lake at Fenelon Falls.

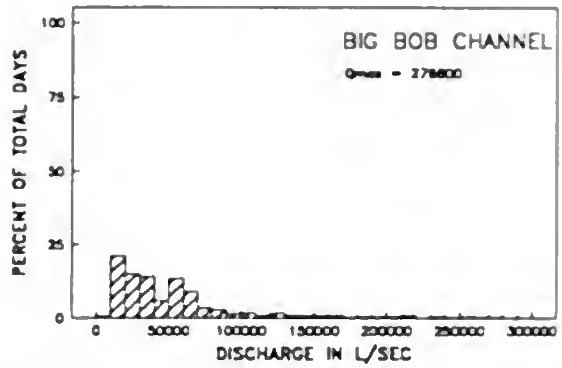

Figure 68. Histogram of daily discharge frequencies estimated for the outlet of Sturgeon Lake at Bobcaygeon.

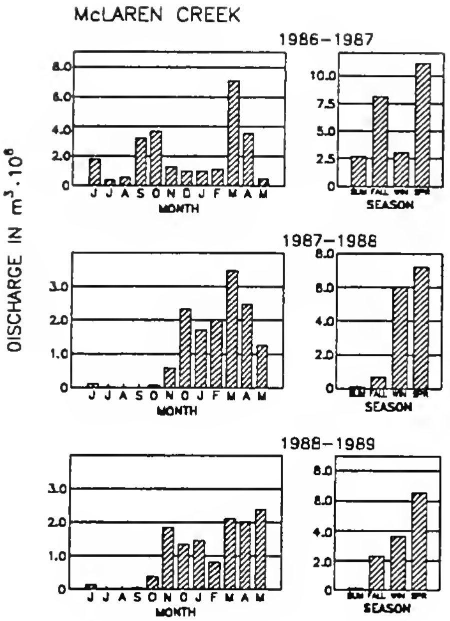

Figure 69. Mean monthly and seasonal discharge for McLaren Creek for the hydrologic years 1986-87, 1987-88, 1988-89.

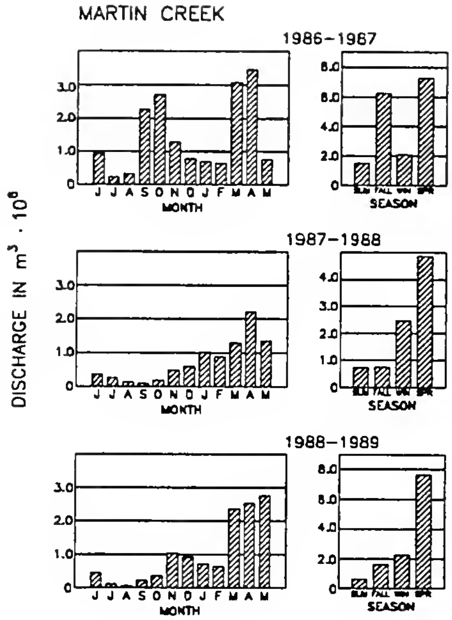

Figure 70. Mean monthly and seasonal discharge for Martin Creek for the hydrologic years 1986-87, 1987-88, 1988-89.

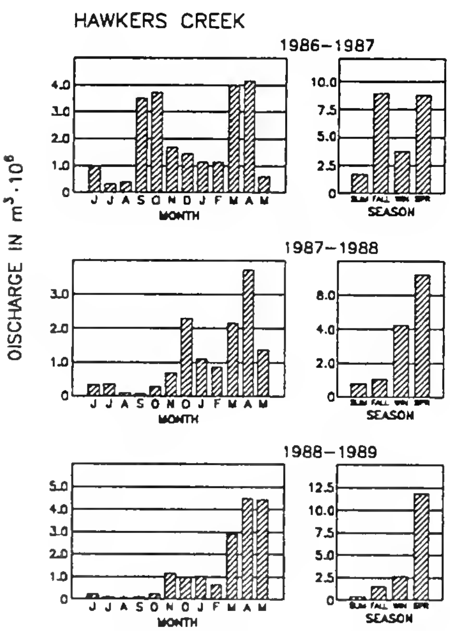

Figure 71. Mean monthly and seasonal discharge for Hawkers Creek for the hydrologic years 1986-87, 1987-88, 1988-89.

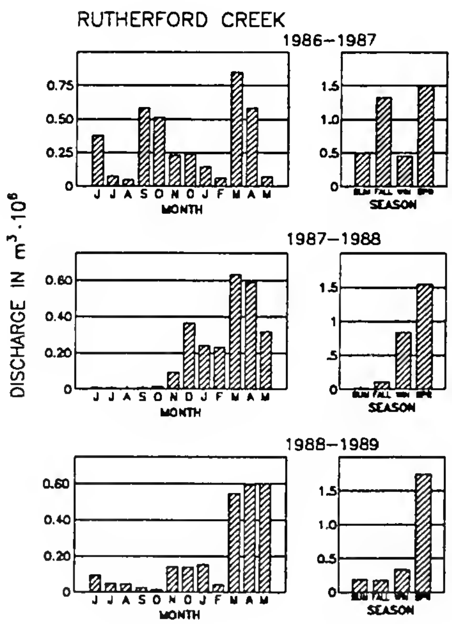

Figure 72. Mean monthly and seasonal discharge for Rutherford Creek for the hydrologic years 1986-87, 1987-88, 1988-89.

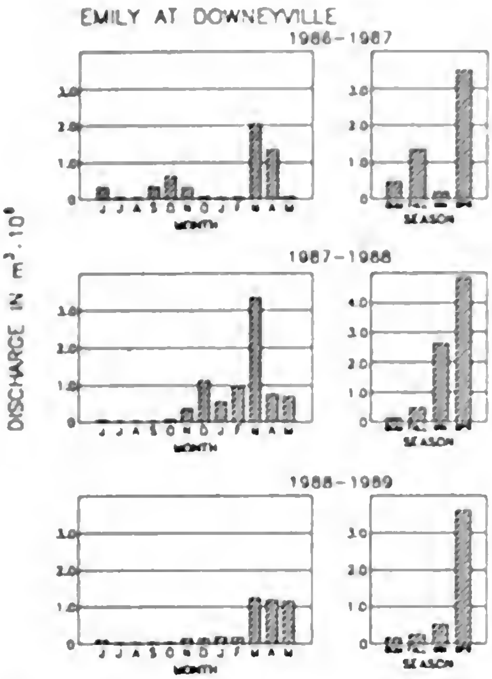

Figure 73. Mean monthly and seasonal discharge for Emily Creek at Downeyville for the hydrologic years 1986-87, 1987-88, 1988-89.

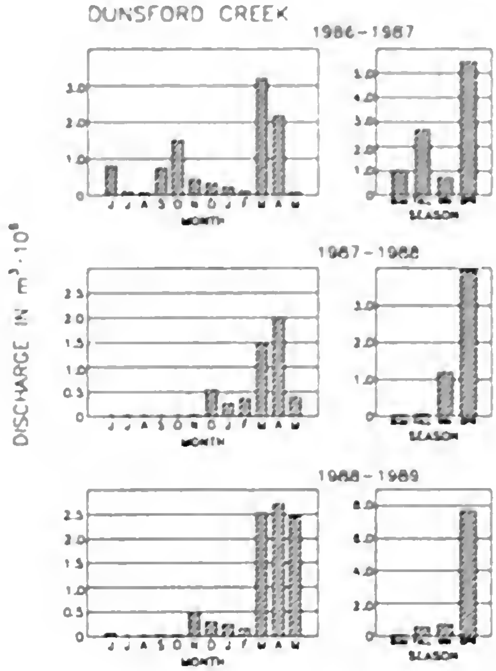

Figure 74. Mean monthly and seasonal discharge for Dunsford Creek for the hydrologic years 1986-87, 1987-88, 1988-89.

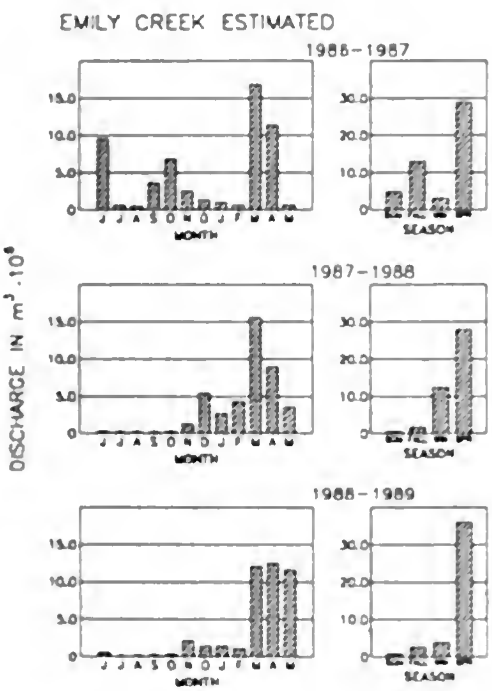

Figure 75. Mean monthly and seasonal discharge estimated for the mouth of Emily Creek for the hydrologic years 1986-87, 1987-88, 1988-89.

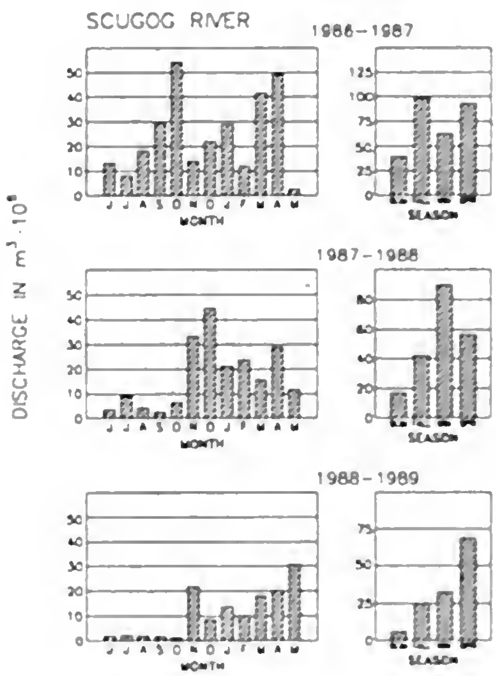

Figure 76. Mean monthly and seasonal discharge for Scugog River for the hydrologic years 1986-87, 1987-88, 1988-89.

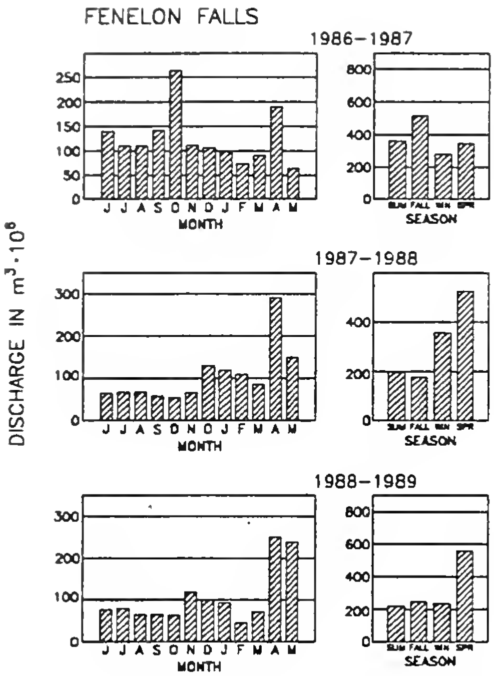

Figure 77. Mean monthly and seasonal discharge for Fenelon Falls for 1986-87, 1987-88, 1988-89.

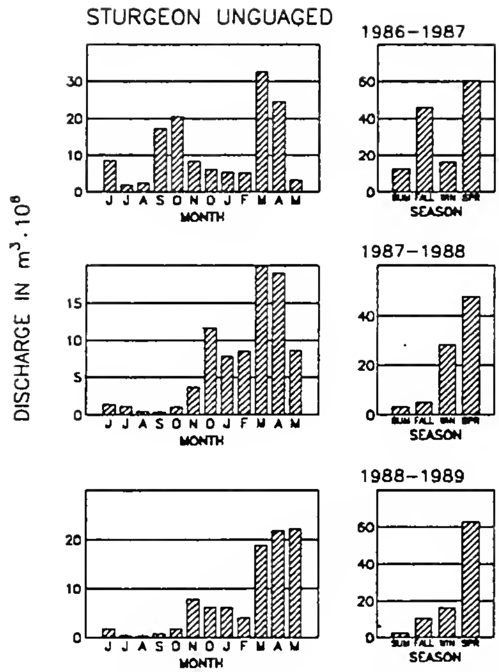

Figure 78. Mean monthly and seasonal discharge for the unguaged portion of the Sturgeon Lake watershed for 1986-87, 1987-88, 1988-89.

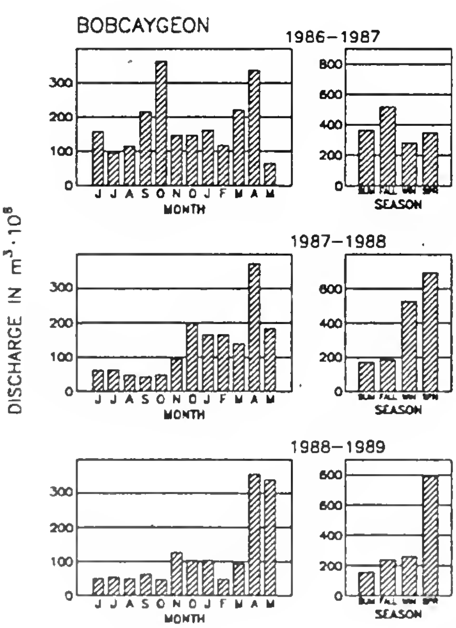

Figure 79. Mean monthly and seasonal discharge for the outlet of Sturgeon Lake at Bobcaygeon for the hydrologic years 1986-87, 1987-88, 1988-89.

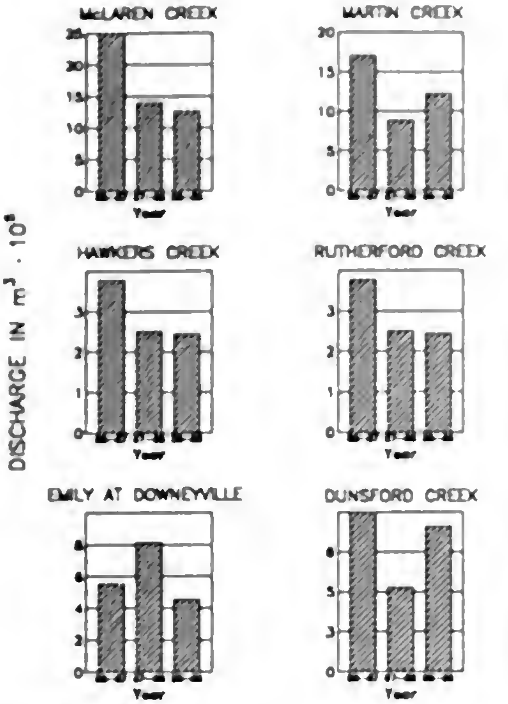

Figure 80. Total annual discharge for subwatersheds of Sturgeon Lake for 1986-87, 1987-88, 1988-89.

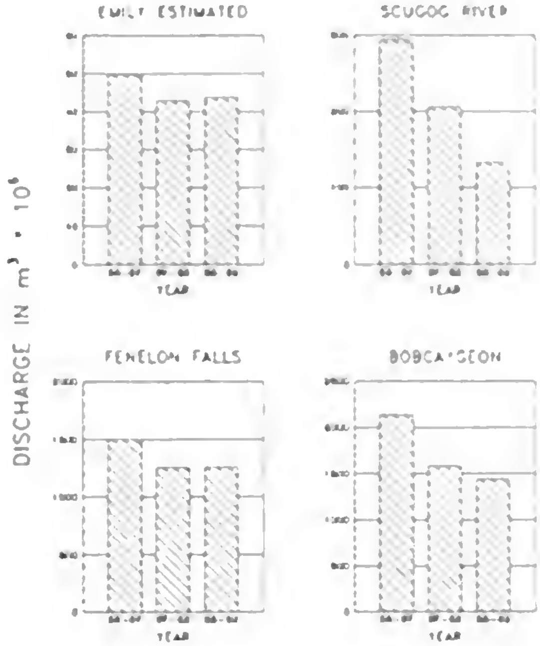

Figure 80, (continued).

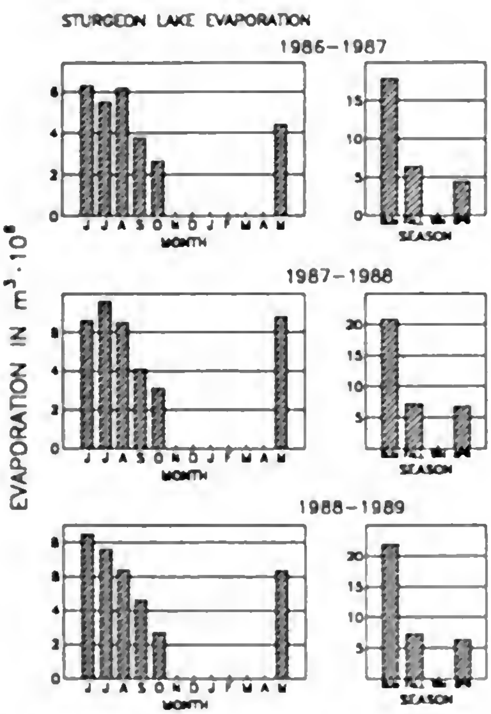

Figure 81. Seasonal and annual contributions of evaporation to the Sturgeon Lake hydrology budget for 1986-87, 1987-88, 1988-89.

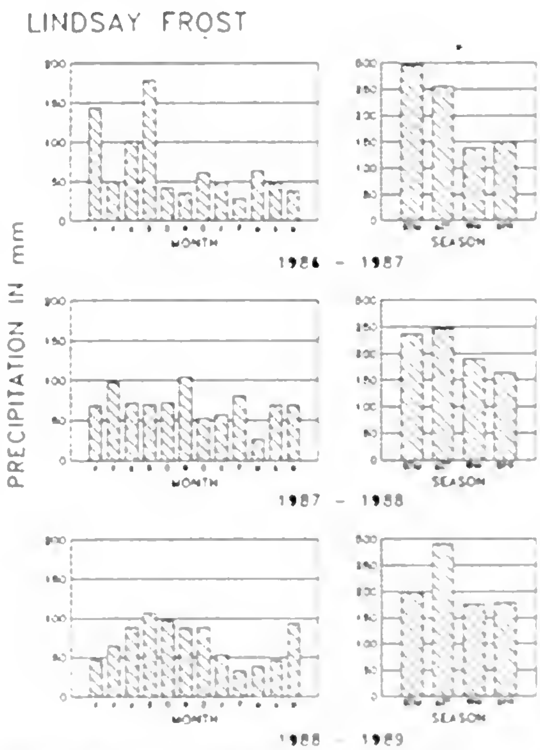

Figure 82. Monthly and seasonal precipitation for Sturgeon Lake for 1986-87, 1987-88, 1988-89.

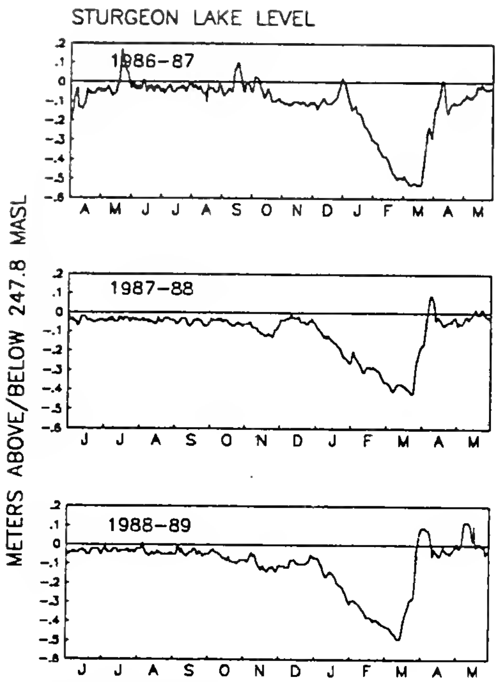

Figure 83. Sturgeon Lake levels recorded at Sturgeon Point for 1986-87, 1987-88, 1988-89. Values are m above or below 247.8 m above sea level.

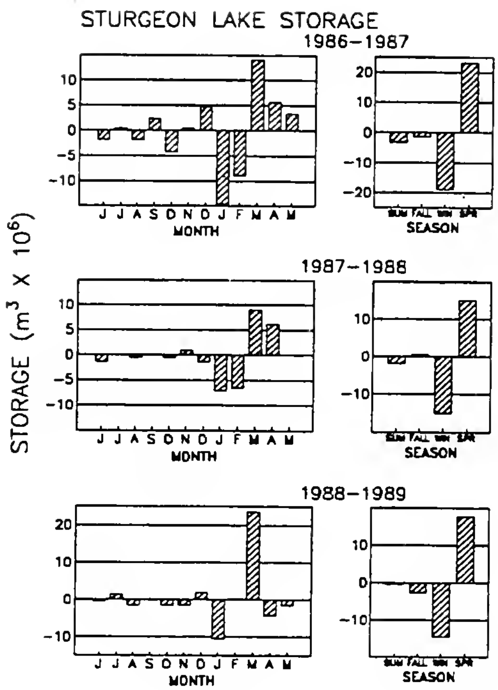

Figure 84. Monthly and seasonal changes in storage for Sturgeon Lake for 1986-87, 1987-88, 1988-89.

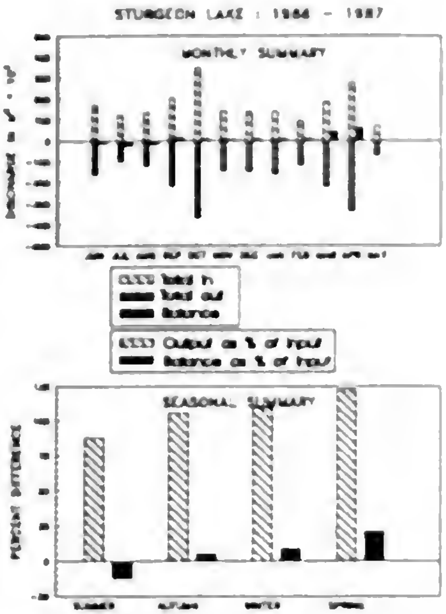

Figure 85: Monthly and seasonal balance of the Sturgeon Lake hydrology budget for the hydrologic year 1986-87

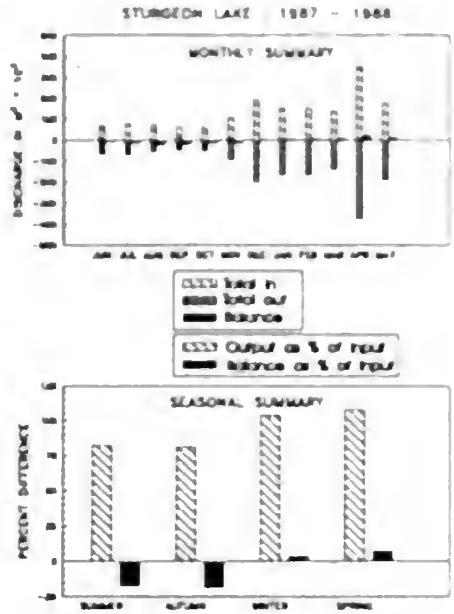

Figure 86: Monthly and seasonal balance of the sturgeon lake hydrology budget for the hydrologic year 1987-88

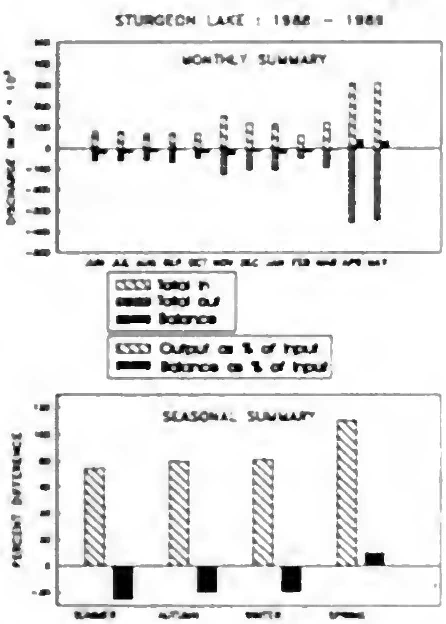

Figure 87: Monthly and seasonal balance of the Sturgeon Lake hydrology budget for the hydrologic year 1988-89

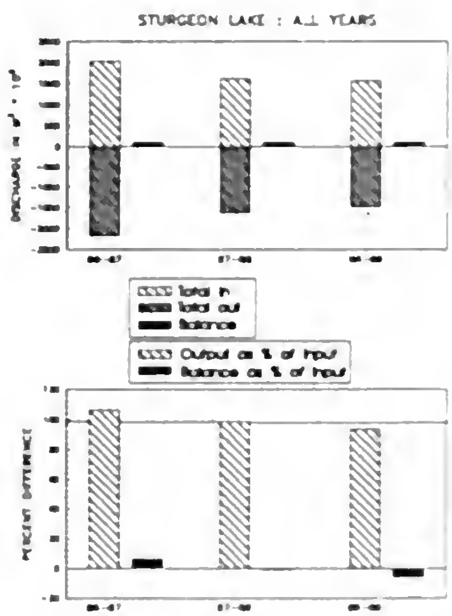

Figure 88: Annual balance of the Sturgeon Lake hydrology budget for the hydrologic years 1986-87,1987-88,1988-89

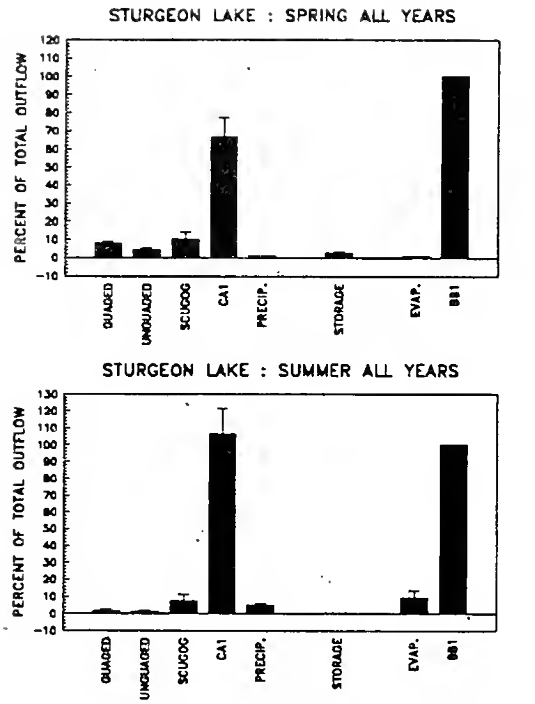

Figure 89: Seasonal averages for terms of the spring and summer Sturgeon Lake hydrology budget for the hydrologic years 1986-87, 1987-88, 1988-89

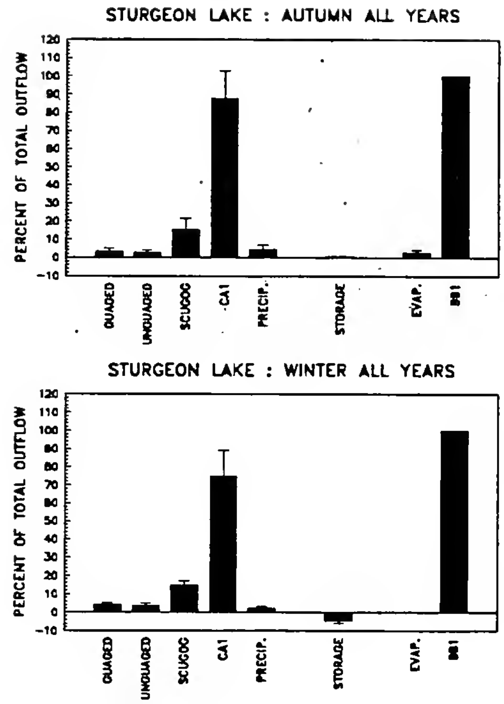

Figure 90: Seasonal averages for terms of the autumn and winter Sturgeon Lake hydrology budget for the hydrologic years 1986-87,1987-88,1988-89

Estimates of annual yield (Table 4) ranged from 15.9% (1988-89) to 61.9% (Hawkers Creek 1986-87). Yields for the spring freshet generally exceeded 100%, reflecting melting of the snowpack (Tables 22-32, Appendix 1). The highest yield, of 465.8%, was recorded for the Emily at Downeyville tributary in March 1988 (Table 28). Low values of 0% were recorded in the summer months for several streams.

Annual evaporation from the surface of Sturgeon Lake ranged from 0.61 to 0.77 m/yr for each study year. Evaporation was greater than for Rice Lake, by values of 0.05, 0.07 and 0.14 m in 1986-87, 1987-88 and 1988-89 respectively. By comparison, evaporation in 7 lakes in Muskoka-Haliburton averaged 0.64 - 0.69 m/yr between 1976 and 1980 (Scheider et al 1983). Higher evaporation figures for Sturgeon Lake are surprising, as annual mean values of air and water temperature, and hours of sunlight, were higher for Rice Lake than for Sturgeon Lake. The difference in evaporation figures may reflect the fact that the evaporation calculations are not based on absolute values of temperature, but on temperature differentials. Figure 91(top panel) shows that higher evaporation from Sturgeon Lake was most often observed during early autumn when the lakes were cooling. At these times, the difference between air and water temperatures (mmiddle panel) were lower in Sturgeon Lake than in Rice Lake partly because Sturgeon Lake cooled more quickly than Rice Lake (bottom panel). A smaller air water temperature gradient would produce lower values of the Bowen ratio (B) and hence greater values for the latent heat of vaporization (LE) in the evaporation equation.

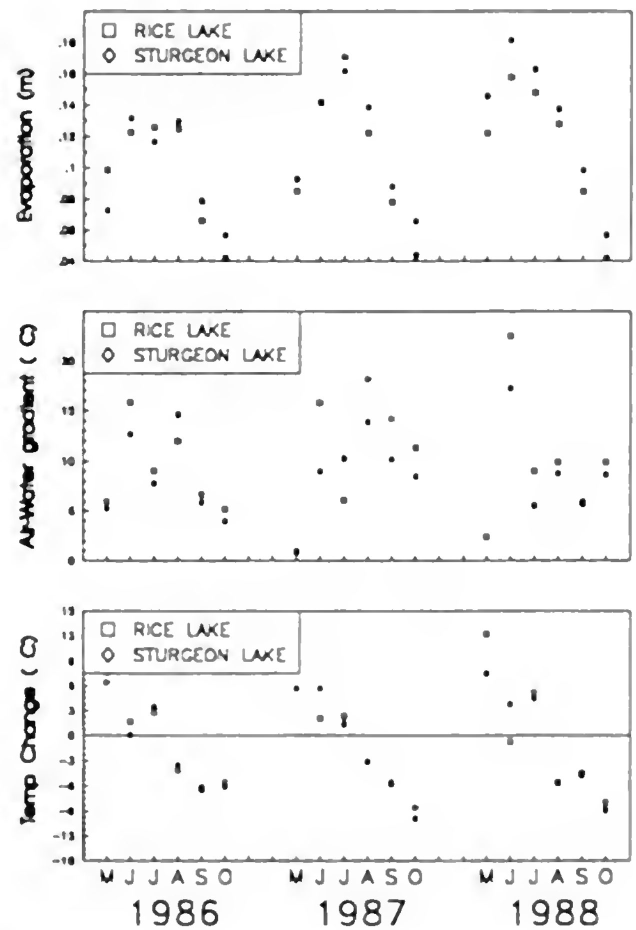

Figure 91: Summary of evaporation differences between Rice and Sturgeon Lake: 1986-1989.

Evaporation during the summer months accounted for approximately 60% of the annual total (Table 14, Figure 81).

Annual precipitation ranged from 0.838 m in 1987-88 to 0.843 m in 1988-89 (Table 14), lower than the 30 year average of 0.856 m (Table 2). Precipitation was highest in the autumns of 1987-88 and 1988-89 and in the summer of 1986-87 (Figure 82).

Monthly changes in the level of Sturgeon Lake were calculated as the difference in water level on the first day of each month. These changes ranged from a drop of 31 cm in January 1987 to a rise of 50 cm in March 1989 (Table 15). Figure 83 shows daily water levels plotted against a base level of 247.8 MASL. Figure 84 summarizes monthly and seasonal changes in whole-lake storage. The annual cycle of water levels on Sturgeon Lake was markedly different from that in Rice Lake (Fig 41). Water levels dropped by approximately 0.4 m each winter, increased to base levels during the spring freshet and were relatively stable between April and October. Rice Lake by contrast was maintained at base levels throughout the winter and showed a transient increase in water levels during the spring freshet.

Two reasons may explain why water level changes in Sturgeon Lake were 2-3 times greater than in Rice Lake. Water level changes in Rice Lake would be damped and their timing changed by the number of lakes dams and locks between Rice and Sturgeon Lakes. In addition the ratios of surface area to volume were 0.29 and 0.42 in Sturgeon and Rice Lakes respectively. The level of Sturgeon lake must therefore fluctuate more to accommodate changes in inflow volume. Annual changes in the level of Sturgeon Lake were -1, -3 and 0 cm in each of the study years (Table 15). Storage contributions to the Sturgeon Lake hydrology budget were thus more important on a monthly or seasonal basis than when balanced out over the course of a hydrologic year (Figure 84).

The hydrologic budgets for Sturgeon lake are summarized in Tables 33 to 37, Appendix 1, and Figures 85 to 90. Individual supply and loss terms are presented on a monthly and seasonal basis in Tables 33 to 36 and the annual budget figures are given in Table 37.

Overall, supply and loss terms for Sturgeon Lake balanced to within 1.1% to 6.7% in each of the three years of the study (Table 37, Figure 88). The balance (outflow-inflow) was positive in 1986-87 and negative in the other two years. In year 2, the balance was 98.9% and the 1.1% error small enough to be considered negligible. The better balance on the Sturgeon Lake budget, compared to Rice Lake, likely reflects a more even distribution of input from several sources. The major inflow at Fenelon Falls accounted for 71-78% of the total hydrology budget and it was based on measurements of discharge for the Gull and Burnt Rivers. Any errors made in the budget were thus more likely to be distributed across several significant input terms so that they were relatively less important.

Monthly hydrology budgets balanced to within 1.3% to 31.4% and seasonal budgets to within 3.5 to 25.4% (Tables 33-36, Appendix 1). Average error for all seasons was greatest (18.7%) in the third year of the study, as it was for Rice Lake. The average annual error for each seasonal balance was greatest (18.2%) for the summer and the balance was closest (10.3%) for the winter. Inflow exceeded output in each summer month of the study and in each autumn month in years 2 and 3. A positive balance (inflow<outflow) occured in the winter of years 1 and 2 and in spring of all years.

Figures 89 and 90 show that, as for Rice Lake, most of the hydrology budget of Sturgeon Lake could be determined by monitoring the inflow at Fenelon Falls and the outflow at Bobcaygeon.

The residence time for water in Sturgeon Lake ranged from a minimum of 14.5 d in April 1988 to a maximum of 114.7 days in September 1987 (Table 21). Figure 49 shows monthly residence times to be lowest in April (13.1-14.5 d) of all three years. Residence time was highest in May of year 1 (74.2d) and September and October of years 2 and 3 respectively (104 and 102 d). Residence time of Sturgeon Lake remained high between June and October (Figure 49), unlike Rice Lake, where it declined quickly before and after July and August maxima. The annual average residence time for Sturgeon Lake increased in each year of the study; from 30 days in year 1 to 45 days in year 3. This was the result of a decreasing inflow volume (Table 37).

Land use and Water Yield

The Bewdley South watershed was the most intensively farmed : 93% of the total area of 2220 ha was cleared for agriculture (Table 38, Appendix 1). The Martin Creek watershed was dominated by dry wooded areas (56%) and only 34% was agricultural. The remaining watersheds ranged from 47% to 77% agricultural land use, 0 to 36% wet woodland, 7 to 57% dry woodland, 0 to 6% marsh and 0 to 3% urban (Table 38, Appendix 1), all determined by digitizing from 1:50,000 topographic maps.

Water yield was not associated with land-use characteristics. Regressions of seasonal water yield on land use characteristics were not significant ($p > 0.18$, Table 39, Appendix1), regardless of the number of independent variables entered into the regression equation. Annual yields could not be explained by land-use characteristics : all regressions were non-significant ($p > 0.19$, Table 39, Appendix 1). Other factors such as slope or soil type may have improved the water yield model but these were not considered.

ACKNOWLEDGEMENTS

Many people contributed to the design and execution of this study. Bruce Kitchen and Blaine Trumbley, of the Trent-Several Waterway, Parks Canada, Peterborough, Ontario, were instrumental in the design of the hydrology network and in providing discharge figures for major tributaries. Bruce Kitchen also assisted in his role on the Technical Committee. Lem Scott's (MOE) advice on network design and continual dedication to quality control in network maintenance is much appreciated. Dennis Onn and Keith Sherman (MOE) had much to do with study design and implementation. MacLaren Plansearch were the primary contractor for network maintenance and much credit is due to Paul Donahue for facilitating quality output as their project coordinator. We also thank Gord Gallant, of the Otonabee Region Conservation Authority, for access to the Hope Mill datalogger records of Indian River stage heights and Reed and Loretta Clarke for making stage observations of the Scugog River at Lindsay. Lloyd Logan (MOE) gave advice on various aspects of hydrology. Ed de Grosbois and Dave Gardner (MOE, Dorset Research Centre) provided the necessary computer support. Jan Beaver and Ken Nicholls (MOE), and Dave Maraldo and Lois Deacon (MNR) assisted in their roles on the Rice-Sturgeon Technical Committee.

REFERENCES

Environment Canada. 1974. Automated streamflow computations. Inland Waters Directorate, Environment Canada, Ottawa, Canada. 82 pp.

Environment Canada. 1981. Canadian Climate Normals, 1951-1980. Temperature and Precipitation, Ontario. Canadian Climate Program Publication, atmospheric Environment Service. UDC: 551.582 (713) 254p.

Fisheries and Environment Canada. 1978. Hydrological Atlas of Canada, Dept. of Supply and Services Canada. EN37-26/1978. Ottawa, Ontario.

Hutchinson, N.J., J.R. Munro, B. Clark, B.P. Neary and J. Beaver. 1993(b). Water chemistry data for the watersheds of Rice and Sturgeon lakes. 1986-1989. Ontario Ministry of the Environment, Dorset Research Centre Data Report Series DR 93/2.

Hutchinson, N.J., B. Clark, J. Munro and B.P. Neary. 1993(c). Nutrient and elemental budgets for the Rice and Sturgeon Lakes. 1986-1989. Ontario Ministry of the Environment, Dorset Research Centre. Data Report Series DR 93/3.

Kawartha Region Conservation Authority. 1981. Watershed Management Strategy, December 1982, 297 pp.

Kleinbaum, D.G. and L.L. Kupper. 1978. Applied regression analysis and other multivariable methods. Wadsworth Publ. Co. Belmont, CA. 486 pp.

Locke, B.A. and L.D. Scott. 1986. Studies of lakes and watersheds in Muskoka-Haliburton, Ontario: Methodology (1976-1985). Ontario Ministry of the Environment, Dorset Research Centre, Data Report Series DR 86/4.

Hutchinson,N.J., B.P. Neary, B. Kitchen, K. Nicholls, J. Beaver and L. Deacon. 1993(d). The Rice and Sturgeon Lakes Nutrient Budget Study, 1986-1989, Final Report. Ontario Ministry of the Environment Technical Report.

Ontario Ministry of the Environment. 1982. Sudbury Environmental Study. Studies of lakes and watersheds near Sudbury, Ontario: Final limnological report. Supplementary Volume to SES 009/82. ISBN 0-7743-7845-X.

Ontario Ministry of the Environment and Ontario Ministry of Natural Resources. 1976. The Kawartha Lakes Water Management Study - Water Quality Assessment (1972-1976). November 1976. 185 pp.

Otonabee Region Conservation Authority. 1983. Watershed Inventory. July, 1983.

Scheider, W.A., C.M. Cox and L.D. Scott. 1983. Hydrological data for lakes and watersheds in the Muskoka-Haliburton Study Area (1976-1980). Ontario Ministry of the Environment, Dorset Research Centre, Data Report Series DR 83/6.

Water Survey of Canada. 1977. "STREAM" Programme. Data Control Section, Water Survey of Canada, Water Resources Branch. Dept. of Environment, Ottawa. 1977.

LIST OF TABLES - APPENDIX 1

Table 3. Physical characteristics of the Rice Lake subwatersheds including drainage areas, gauging structures, period of operation and annual hydrological statistics.

Surface Area = 10,010 ha.
Watershed Area = 914,125 ha.
Residence Time = 33.9 days (3 yr ave.)

Watershed	Bewdley N.	Bewdley S.	Indian River	Ouse River	Otonabee R	Trent R (Outflow)	Unguaged
Watershed Area (ha)	631	2,220	25,800	28,200	822,530	914,125	24,734
Gauging Structure	Weir pool notch	Weir pool notch	Dam Flume	WSC	TSW	TSW	Pro-rated
Period of Operation	8604-8905	8604-8905	8604-8905	8604-8905	8604-8905	8604-8905	8604-8905
Missing data (%)	14	8	6	0	0	0	100
Maximum Q (m3/s)	392	3340	17812	26500	364600	367100	na
Minimum Q (m3/s)	15.6	7.9	314	50	10800	10800	na
Median (m3/s)	51.0	71.6	2136	1150	73000	72800	na
1st Quartile (m3/s)	45.1	57.9	1720	426	24800	32100	na
3rd Quartile (m3/s)	65.5	93.9	2763	25500	109000	113000	na
Total Q 1986-87	2.03	3.57	84.35	83.12	3281	3246	75.3
(m3 x E6) 1987-88	1.94	4.34	73.41	64.16	2233	2366	62.6
1988-89	1.70	3.46	75.59	45.63	2100	2181	55.0
Areal Runoff 1986-87	0.32	0.16	0.33	0.29	0.40	0.36	0.30
(meters) 1987-88	0.31	0.20	0.28	0.23	0.27	0.26	0.25
1988-89	0.27	0.16	0.29	0.16	0.26	0.24	0.22
Annual Yield 1986-87	40.3	20.1	40.9	36.8	49.9	44.4	37.5
(%) 1987-88	37.4	23.8	34.6	27.7	32.9	31.6	30.4
1988-89	39.3	22.7	42.7	23.6	37.9	34.8	32.1
Baseflow 1986-87	16	47	1,051	168	10,800	10,800	na
(L/s) 1987-88	25	44	314	73	11,600	13,000	na
1988-89	8	8	902	50	13,300	11,400	na

Table 4. Physical characteristics of the Sturgeon Lake subwatersheds including drainage areas, gauging structures, period of operation and hydrological statistics.

Surface Area = 4,710 ha.

Watershed Area = 476,377 ha.

Residence Time = 38.6 days (3 yr ave.)

Watershed	Martin	Hawkers	Rutherford	McLaren	Dunsford	Emily at Downeyville	Emily * (Estimated)	Bobcaygeon (Outflow)	Scugog	Fenelon Falls	Unguaged
Watershed Area (ha)	3,473	4,433	1,823	5,339	2,439	2,772	16,697	476,377	96,370	324,500	19,032
Gauging Structure	Stilling well with control	Stilling well with control	Stilling well with control	Stilling well with control	Stilling well with control	Stilling well with control	Estimated	Controlled structures*	Calculated*	Controlled structures*	Estimated pro-rated
Period of Operation	8604-8905	8604-8905	8604-8905	8604-8905	8604-8905	8604-8905	8604-8905	8604-8905	8604-8905	8604-8905	8604-8905
Missing data (%)	26	11	23	16	17	20	100	0	0	0	100
Maximum Q (m3/s)	4940	9800	2280	4840	6420	3940	29575	276600	34000	188007	na
Minimum Q (m3/s)	11.00	0.10	0	0	0.02	2.66	17.40	9500	160	9176	na
Median (m3/s)	262	0.36	39.0	308	76.7	57.0	443	39100	4050	34177	na
1st Quartile (m3/s)	121	109	14.0	80.3	13.5	20.0	132	24100	810	24376	na
3rd Quartile (m3/s)	542	609	112	774	227	200	1464	66300	11200	48036	na
Total Q 1986-87	17.08	23.06	3.78	24.92	9.99	5.56	49.84	2135	294	1502	153
(m3 x E6) 1987-88	8.80	13.31	2.50	14.03	5.25	8.14	42.93	1579	205	1256	97
1988-89	12.21	16.30	2.44	12.60	9.09	4.57	43.75	1439	133	1261	102
Areal Runoff 1986-87	0.492	0.520	0.207	0.467	0.410	0.201	0.298	0.448	0.305	0.463	0.805
(meters) 1987-88	0.253	0.300	0.137	0.263	0.216	0.294	0.257	0.331	0.213	0.387	0.507
1988-89	0.351	0.368	0.134	0.236	0.373	0.165	0.262	0.302	0.138	0.388	0.535
Annual Yield 1986-87	58.6	61.9	24.6	55.6	48.8	23.9	35.5	53.4	36.3	55.1	95.9
(%) 1987-88	30.2	35.8	16.3	31.4	25.8	35.1	30.7	39.6	25.4	46.2	60.5
1988-89	38.9	43.7	15.9	26.1	44.2	19.6	31.1	35.8	16.3	46.0	63.5
Baseflow 1986-87	20	41	2	3	6	12	57	14,300	380	13,718	na
(L/s) 1987-88	18	6	0	0	1	3	29	9,500	470	10,993	na
1988-89	11	0	0	0	0	5	17	9,700	160	9,848	na

*Dunsford + Emily at Downeyville X 16,697 / 5211

Table 5. Stage-discharge equations determined for each station on the Rice Lake hydrology monitoring network.

Bewdley North	Before Culvert	Q= 3.91 * S ** 3.63
	After Culvert	Q= 1.63 * S ** 3.15
Bewdley South	Entire period notch 1	Q= 2.94 * S ** 4.90
	notch 2	Q=11.93 * S ** 1.80
Indian River	Ice-free 8603-8612	Q=31.00 * S ** 1.42
	Ice-free 8701-8905	Q=22.69 * S ** 2.37
	Ice-cover	Q= 3.07 * S ** 1.35

Table 6. Stage-discharge equations determined for each station on the Sturgeon Lake hydrology monitoring network.

Martin	Ice-free notch 1	Q=13.72 * S ** 1.98
	notch 2	Q=10.00 * S ** 1.43
	Ice-cover	Q= 2.53 * S ** 1.01
Hawkers	Entire period	Q=13.71 * S ** 2.08
Rutherford	Entire period	Q= 5.26 * S ** 3.57
Dunsford	Ice-free	Q=11.05 * S ** 2.45
	Ice-cover	Q= 3.69 * S ** 2.29
Emily Creek At Downeyville	Ice-free notch 1	Q= 4.20 * S ** 1.90
	notch 2	Q=11.84 * S ** 1.54
	Drought period	Q= 0.68 * S ** 0.10
	Ice-cover	Q= 0.80 * S ** 1.70
McLaren	Ice-free notch 1	Q= 1.22 * S ** 1.22
	notch 2	Q= 6.12 * S ** 1.41
	Ice-cover	Q= 1.97 * S ** 2.02

Table 7. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures for the Bewdley North (BYN) subwatershed (area = 631 ha) of Rice Lake for the hydrologic years 1986-87, 1987-88, 1988-89.

Monthly Summary

Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8606	0.122	0.247	0.039	31.9	48
8607	0.033	0.125	0.020	61.0	29
8608	0.105	0.138	0.022	20.7	16
8609	0.159	0.179	0.028	17.9	37
8610	0.049	0.161	0.026	51.9	49
8611	0.038	0.149	0.024	62.1	47
8612	0.069	0.194	0.031	44.3	49
8701	0.040	0.141	0.022	55.2	47
8702	0.034	0.110	0.017	51.2	39
8703	0.049	0.236	0.037	75.9	53
8704	0.057	0.229	0.036	64.1	47
8705	0.044	0.124	0.020	45.2	38
8706	0.049	0.112	0.018	35.9	32
8707	0.078	0.110	0.018	22.5	35
8708	0.084	0.094	0.015	17.7	26
8709	0.068	0.101	0.016	23.5	29
8710	0.078	0.133	0.021	27.0	25
8711	0.122	0.176	0.028	22.8	50
8712	0.063	0.156	0.025	39.4	41
8801	0.040	0.235	0.037	92.8	44
8802	0.066	0.197	0.031	47.1	63
8803	0.026	0.246	0.039	148.7	57
8804	0.086	0.214	0.034	39.2	65
8805	0.060	0.166	0.026	44.1	54
8806	0.032	0.131	0.021	63.9	40
8807	0.047	0.080	0.013	27.0	28
8808	0.048	0.099	0.016	32.3	30
8809	0.080	0.123	0.019	24.3	47
8810	0.093	0.127	0.020	21.7	47
8811	0.069	0.123	0.020	28.4	47
8812	0.059	0.148	0.023	39.6	45
8901	0.036	0.181	0.029	78.9	44
8902	0.025	0.118	0.019	74.3	40
8903	0.059	0.245	0.039	66.0	8
8904	0.043	0.160	0.025	58.3	23
8905	0.094	0.167	0.026	28.3	8

Seasonal Summary

Season	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
summer 1986	0.260	0.510	0.081	31.0	16
autumn 1986	0.246	0.490	0.078	31.5	37
winter 1987	0.144	0.445	0.070	49.0	39
spring 1987	0.150	0.589	0.093	62.5	38
TOTAL	0.800	2.033	0.322	40.3	16
summer 1987	0.211	0.316	0.050	23.7	26
autumn 1987	0.269	0.411	0.065	24.2	25
winter 1988	0.169	0.588	0.093	55.1	41
spring 1988	0.172	0.625	0.099	57.6	54
TOTAL	0.821	1.941	0.308	37.4	25
summer 1988	0.128	0.309	0.049	38.4	28
autumn 1988	0.242	0.373	0.059	24.5	47
winter 1989	0.121	0.448	0.071	58.7	40
spring 1989	0.196	0.572	0.091	46.3	8
TOTAL	0.686	1.702	0.270	39.3	8

Table 8. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures for the Bewdley South (BYS) subwatershed (area = 2,220 ha) of Rice Lake for the hydrologic years 1986-87, 1987-88, 1988-89.

Monthly Summary

Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8606	0.122	0.199	0.009	7.3	67
8607	0.033	0.174	0.008	24.1	59
8608	0.105	0.195	0.009	8.3	47
8609	0.159	0.277	0.012	7.8	62
8610	0.049	0.260	0.012	23.8	77
8611	0.038	0.219	0.010	25.9	74
8612	0.069	0.324	0.015	21.1	77
8701	0.040	0.268	0.012	29.9	93
8702	0.034	0.190	0.009	25.2	71
8703	0.049	0.651	0.029	59.6	92
8704	0.057	0.577	0.026	45.8	91
8705	0.044	0.231	0.010	23.9	79
8706	0.049	0.195	0.009	17.8	69
8707	0.078	0.183	0.008	10.6	61
8708	0.084	0.154	0.007	8.2	49
8709	0.068	0.149	0.007	9.8	50
8710	0.078	0.161	0.007	9.3	53
8711	0.122	0.178	0.008	6.5	44
8712	0.063	0.258	0.012	18.5	64
8801	0.040	0.422	0.019	47.3	45
8802	0.066	0.268	0.012	18.2	62
8803	0.026	1.895	0.085	325.8	70
8804	0.086	0.293	0.013	15.3	78
8805	0.060	0.183	0.008	13.9	59
8806	0.032	0.147	0.007	20.4	53
8807	0.047	0.141	0.006	13.6	51
8808	0.048	0.152	0.007	14.1	49
8809	0.080	0.167	0.008	9.4	44
8810	0.093	0.154	0.007	7.4	35
8811	0.069	0.161	0.007	10.5	52
8812	0.059	0.196	0.009	14.9	49
8901	0.036	0.496	0.022	61.3	52
8902	0.025	0.734	0.033	131.2	44
8903	0.059	0.709	0.032	54.3	8
8904	0.043	0.156	0.007	16.2	23
8905	0.094	0.245	0.011	11.8	8

Seasonal Summary

	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
summer 1986	0.260	0.57	0.026	9.8	47
autumn 1986	0.246	0.76	0.034	13.8	62
winter 1987	0.144	0.78	0.035	24.5	71
spring 1987	0.150	1.46	0.066	44.0	79
TOTAL	0.800	3.57	0.161	20.1	47
summer 1987	0.211	0.53	0.024	11.4	49
autumn 1987	0.269	0.49	0.022	8.2	44
winter 1988	0.169	0.95	0.043	25.2	45
spring 1988	0.172	2.37	0.107	62.0	59
TOTAL	0.821	4.34	0.195	23.8	44
summer 1988	0.128	0.44	0.020	15.5	49
autumn 1988	0.242	0.48	0.022	9.0	35
winter 1989	0.121	1.43	0.064	53.2	44
spring 1989	0.196	1.11	0.050	25.5	8
TOTAL	0.686	3.46	0.156	22.7	8

Table 9. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures for the Ouse River (OE1) subwatershed (area = 28,200 ha) of Rice Lake for the hydrologic years 1986-87, 1987-88, 1988-89.

Monthly Summary

Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8606	0.122	4.90	0.017	14.2	967
8607	0.033	2.78	0.010	30.3	449
8608	0.105	1.25	0.004	4.2	292
8609	0.159	1.58	0.006	3.5	168
8610	0.049	6.71	0.024	48.3	811
8611	0.038	4.35	0.015	40.5	1180
8612	0.069	4.77	0.017	24.4	1170
8701	0.040	5.99	0.021	52.6	1370
8702	0.034	2.72	0.010	28.4	980
8703	0.049	6.83	0.024	49.2	907
8704	0.057	34.06	0.121	213.0	4770
8705	0.044	7.18	0.025	58.4	1210
8706	0.049	2.82	0.010	20.3	537
8707	0.078	1.31	0.005	6.0	296
8708	0.084	0.42	0.001	1.8	82
8709	0.068	0.31	0.001	1.6	73
8710	0.078	0.68	0.002	3.1	126
8711	0.122	1.83	0.006	5.3	258
8712	0.063	6.13	0.022	34.5	683
8801	0.040	5.84	0.021	51.6	815
8802	0.066	5.29	0.019	28.4	790
8803	0.026	4.40	0.016	59.6	1160
8804	0.086	25.13	0.089	103.1	1080
8805	0.060	10.00	0.035	59.5	2280
8806	0.032	3.95	0.014	43.2	421
8807	0.047	0.75	0.003	5.7	117
8808	0.048	0.33	0.001	2.4	50
8809	0.080	0.23	0.001	1.0	50
8810	0.093	0.37	0.001	1.4	58
8811	0.069	1.53	0.005	7.9	222
8812	0.059	1.58	0.006	9.5	333
8901	0.036	2.22	0.008	21.6	360
8902	0.025	2.70	0.010	38.0	545
8903	0.059	3.88	0.014	23.4	305
8904	0.043	15.80	0.056	129.1	1050
8905	0.094	12.30	0.044	46.6	2680

Seasonal Summary

	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
summer 1986	0.260	8.93	0.032	12.2	292
autumn 1986	0.246	12.64	0.045	18.2	168
winter 1987	0.144	13.48	0.048	33.3	980
spring 1987	0.150	48.07	0.170	114.0	907
TOTAL	0.800	83.12	0.295	36.8	168
summer 1987	0.211	4.55	0.016	7.6	82
autumn 1987	0.269	2.81	0.010	3.7	73
winter 1988	0.169	17.26	0.061	36.2	683
spring 1988	0.172	39.53	0.140	81.4	1080
TOTAL	0.821	64.16	0.228	27.7	73
summer 1988	0.128	5.03	0.018	14.0	50
autumn 1988	0.242	2.12	0.008	3.1	50
winter 1989	0.121	6.49	0.023	19.1	333
spring 1989	0.196	31.98	0.113	57.9	305
TOTAL	0.686	45.63	0.162	23.6	50

Table 10. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures for the Indian River (IR1) subwatershed (area = 25,800 ha) of Rice Lake for the hydrologic years 1986-87, 1987-88, 1988-89.

Monthly Summary						Seasonal Summary					
Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)		Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8606	0.122	7.58	0.029	24.0	2287						
8607	0.033	4.79	0.019	57.1	1505	summer 1986					
8608	0.105	4.52	0.018	16.6	1357		0.260	16.90	0.065	25.2	1357
8609	0.159	6.59	0.026	16.1	1051						
8610	0.049	8.15	0.032	64.2	1847	autumn 1986					
8611	0.038	6.30	0.024	64.1	1392		0.246	21.04	0.082	33.1	1051
8612	0.069	5.52	0.021	30.8	1316						
8701	0.040	4.38	0.017	42.0	1491	winter 1987					
8702	0.034	5.07	0.020	58.0	1719		0.144	14.97	0.058	40.4	1316
8703	0.049	10.83	0.042	85.3	2410						
8704	0.057	15.76	0.061	107.7	2057	spring 1987					
8705	0.044	4.85	0.019	43.1	1144		0.150	31.44	0.122	81.5	1719
					TOTAL		0.800	84.34	0.327	40.9	1051
8706	0.049	4.12	0.016	32.3	1230						
8707	0.078	5.89	0.023	29.4	1768	summer 1987					
8708	0.084	5.23	0.020	24.1	1768		0.211	15.23	0.059	28.0	1230
8709	0.068	5.17	0.020	29.3	1861						
8710	0.078	5.38	0.021	26.8	1762	autumn 1987					
8711	0.122	4.85	0.019	15.3	1363		0.269	15.39	0.060	22.2	1762
8712	0.063	6.45	0.025	39.8	1579						
8801	0.040	5.29	0.020	51.0	1578	winter 1988					
8802	0.066	4.12	0.016	24.1	1316		0.169	15.86	0.061	36.3	1316
8803	0.026	8.15	0.032	120.6	314						
8804	0.086	11.88	0.046	53.3	3145	spring 1988					
8805	0.060	6.88	0.027	44.8	2113		0.172	26.92	0.104	60.6	314
					TOTAL		0.821	73.41	0.285	34.6	314
8806	0.032	5.66	0.022	67.7	1522						
8807	0.047	6.47	0.025	53.3	2130	summer 1988					
8808	0.048	5.55	0.022	44.6	1742		0.128	17.68	0.069	53.7	1522
8809	0.080	6.46	0.025	31.3	2153						
8810	0.093	5.85	0.023	24.4	1979	autumn 1988					
8811	0.069	5.72	0.022	32.2	1430		0.242	18.03	0.070	28.9	1430
8812	0.059	3.11	0.012	20.4	902						
8901	0.036	3.66	0.014	39.0	1238	winter 1989					
8902	0.025	2.98	0.012	45.8	1101		0.121	9.76	0.038	31.3	902
8903	0.059	9.32	0.036	61.5	1316						
8904	0.043	10.52	0.041	94.0	2590	spring 1989					
8905	0.094	10.28	0.040	42.6	2464		0.196	30.13	0.117	59.6	1316
					TOTAL		0.686	75.59	0.293	42.7	902

Table 11. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures for the Otonabee River (OT1) subwatershed (area = 822,530 ha) of Rice Lake for the hydrologic years 1986-87, 1987-88, 1988-89.

Monthly Summary

Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8606	0.122	277	0.036	29.6	26000
8607	0.033	155	0.020	62.1	19200
8608	0.105	105	0.014	13.0	19400
8609	0.159	194	0.025	16.0	35300
8610	0.049	522	0.068	138.8	130000
8611	0.038	243	0.032	83.3	73200
8612	0.069	241	0.032	45.4	81500
8701	0.040	275	0.036	89.1	78500
8702	0.034	228	0.030	88.1	90300
8703	0.049	237	0.031	63.0	76200
8704	0.057	500	0.065	115.1	88100
8705	0.044	73.9	0.010	22.1	10800
8706	0.049	69.2	0.009	18.3	18600
8707	0.078	52.2	0.007	8.8	18200
8708	0.084	467	0.061	72.5	15300
8709	0.068	38.7	0.005	7.4	11600
8710	0.078	46.5	0.006	7.8	15500
8711	0.122	116	0.015	12.4	22100
8712	0.063	239	0.031	49.6	69800
8801	0.040	297	0.039	96.5	90400
8802	0.066	277	0.036	54.8	91300
8803	0.026	222	0.029	110.9	67600
8804	0.086	398	0.052	60.1	70400
8805	0.060	275	0.036	60.2	61200
8806	0.032	112	0.015	45.1	14300
8807	0.047	45.9	0.006	12.8	15500
8808	0.048	54.0	0.007	14.6	15400
8809	0.080	45.5	0.006	7.4	13300
8810	0.093	81.5	0.011	11.5	16700
8811	0.069	153	0.020	29.1	27900
8812	0.059	209	0.027	46.2	57400
8901	0.036	218	0.029	78.4	58000
8902	0.025	165	0.022	85.3	35400
8903	0.059	103	0.013	22.8	32700
8904	0.043	396	0.052	119.1	78300
8905	0.094	371	0.049	51.8	13500

Seasonal Summary

	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
summer 1986	0.260	537	0.070	26.9	19200
autumn 1986	0.246	959	0.125	50.9	35300
winter 1987	0.144	745	0.097	67.8	81500
spring 1987	0.150	811	0.106	70.9	10800
TOTAL	0.800	3052	0.399	49.9	10800
summer 1987	0.211	588	0.077	36.4	15300
autumn 1987	0.269	202	0.026	9.8	11600
winter 1988	0.169	813	0.106	62.8	69800
spring 1988	0.172	894	0.117	67.9	61200
TOTAL	0.821	2497	0.326	39.7	11600
summer 1988	0.128	212	0.028	21.7	14300
autumn 1988	0.242	280	0.037	15.1	13300
winter 1989	0.121	592	0.077	64.1	35400
spring 1989	0.196	870	0.114	58.0	13500
TOTAL	0.686	1954	0.255	37.2	13300

Table 12. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures for the unguaged portion of the Rice Lake watershed (UNG) (area = 24,734 ha) for the hydrologic years 1986-87, 1987-88, 1988-89.

Monthly Summary

Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)
8606	0.122	5.62	0.023	18.6
8607	0.033	3.42	0.014	42.6
8608	0.105	2.65	0.011	10.2
8609	0.159	3.75	0.015	9.5
8610	0.049	6.64	0.027	54.6
8611	0.038	4.79	0.019	50.9
8612	0.069	4.70	0.019	27.4
8701	0.040	4.69	0.019	46.9
8702	0.034	3.52	0.014	42.0
8703	0.049	8.07	0.033	66.3
8704	0.057	22.0	0.089	157
8705	0.044	5.39	0.022	50.0
8706	0.049	3.15	0.013	25.8
8707	0.078	3.26	0.013	17.0
8708	0.084	2.56	0.010	12.3
8709	0.068	2.49	0.010	14.7
8710	0.078	2.76	0.011	14.3
8711	0.122	3.06	0.012	10.1
8712	0.063	5.65	0.023	36.3
8801	0.040	5.13	0.021	51.6
8802	0.066	4.30	0.017	26.2
8803	0.026	6.39	0.026	98.7
8804	0.086	16.3	0.066	76.4
8805	0.060	7.50	0.030	50.8
8806	0.032	4.30	0.017	53.7
8807	0.047	3.24	0.013	27.8
8808	0.048	2.67	0.011	22.3
8809	0.080	3.03	0.012	15.3
8810	0.093	2.83	0.011	12.3
8811	0.069	3.28	0.013	19.3
8812	0.059	2.19	0.009	15.0
8901	0.036	2.85	0.012	31.7
8902	0.025	2.84	0.011	45.6
8903	0.059	6.16	0.025	42.3
8904	0.043	11.6	0.047	108
8905	0.094	10.0	0.040	43.2

Seasonal Summary

Season	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)
summer 1986	0.260	11.7	0.047	18.2
autumn 1986	0.246	15.2	0.061	24.9
winter 1987	0.144	12.9	0.052	36.3
spring 1987	0.150	35.5	0.143	95.9
TOTAL	0.800	75.3	0.304	38.0
summer 1987	0.211	9.0	0.036	17.2
autumn 1987	0.269	8.3	0.034	12.5
winter 1988	0.169	15.1	0.061	36.0
spring 1988	0.172	30.2	0.122	70.9
TOTAL	0.821	62.6	0.253	30.8
summer 1988	0.128	10.2	0.041	32.3
autumn 1988	0.242	9.1	0.037	15.3
winter 1989	0.121	7.9	0.032	26.4
spring 1989	0.196	27.7	0.112	57.3
TOTAL	0.686	55.0	0.222	32.4

Table 13. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures for the Trent River at Hastings outlet (TT1) (watershed area = 914,125 ha) of Rice Lake for the hydrologic years 1986-87, 1987-88, 1988-89.

Monthly Summary

Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8606	0.122	252	0.028	22.5	32500
8607	0.033	103	0.011	34.6	22200
8608	0.105	138	0.015	14.3	27400
8609	0.159	330	0.036	22.7	35900
8610	0.049	545	0.060	121	73700
8611	0.038	219	0.024	63.0	54100
8612	0.069	263	0.029	41.4	75800
8701	0.040	303	0.033	82.0	91600
8702	0.034	211	0.023	68.1	79500
8703	0.049	290	0.032	64.5	79200
8704	0.057	518	0.057	99.9	22500
8705	0.044	75.0	0.008	18.8	10800
8706	0.049	81.5	0.009	18.1	13400
8707	0.078	61.9	0.007	8.72	13000
8708	0.084	51.7	0.006	6.73	13000
8709	0.068	69.5	0.008	11.1	15600
8710	0.078	82.4	0.009	11.6	24400
8711	0.122	160	0.017	14.3	32200
8712	0.063	329	0.036	57.1	70500
8801	0.040	306	0.034	83.4	97000
8802	0.066	276	0.030	45.6	88700
8803	0.026	247	0.027	103	61500
8804	0.086	432	0.047	54.7	86800
8805	0.060	270	0.030	49.5	34500
8806	0.032	63.1	0.007	21.3	12700
8807	0.047	55.5	0.006	12.9	12300
8808	0.048	46.1	0.005	10.4	11400
8809	0.080	68.5	0.007	9.35	14200
8810	0.093	113	0.012	13.3	23400
8811	0.069	242	0.026	38.6	32000
8812	0.059	178	0.019	32.9	50800
8901	0.036	245	0.027	73.5	76200
8902	0.025	139	0.015	60.5	36100
8903	0.059	184	0.020	34.2	38500
8904	0.043	426	0.047	107	57300
8905	0.094	421	0.046	49.2	47400

Seasonal Summary

Season	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
summer 1986	0.260	493	0.054	20.7	22200
autumn 1986	0.246	1094	0.120	48.6	35900
winter 1987	0.144	776	0.085	59.2	75800
spring 1987	0.150	883	0.097	64.7	10800
TOTAL	0.800	3246	0.356	44.4	10800
summer 1987	0.211	195	0.021	10.1	13000
autumn 1987	0.269	312	0.034	12.7	15600
winter 1988	0.169	911	0.100	58.9	70500
spring 1988	0.172	948	0.104	60.3	34500
TOTAL	0.821	2366	0.259	31.6	13000
summer 1988	0.128	165	0.018	14.1	11400
autumn 1988	0.242	424	0.046	19.2	14200
winter 1989	0.121	562	0.062	51.0	36100
spring 1989	0.196	1030	0.113	57.7	38500
TOTAL	0.686	2181	0.239	34.8	11400

Table 14. Monthly, seasonal and annual precipitation and evaporation for Rice and Sturgeon Lakes for the hydrologic years 1986-87, 1987-88, 1988-89

	Monthly Summary				Seasonal Summary			
Month	Rice Precip (m)	Rice Evap (m)	Sturgeon Precip (m)	Sturgeon Evap. (m)	Rice Precip (m)	Rice Evap (m)	Sturgeon Precip (m)	Sturgeon Evap (m)
8606	0.122	0.122	0.144	0.132				
8607	0.033	0.124	0.050	0.117	summer 1986			
8608	0.105	0.124	0.101	0.130	0.260	0.370	0.295	0.379
8609	0.159	0.065	0.178	0.079				
8610	0.049	0.041	0.042	0.057	autumn 1986			
8611	0.038	0	0.036	0	0.246	0.106	0.256	0.136
8612	0.069	0	0.061	0				
8701	0.040	0	0.050	0	winter 1987			
8702	0.034	0	0.028	0	0.144	0	0.139	0
8703	0.049	0	0.063	0				
8704	0.057	0	0.049	0	spring 1987			
8705	0.044	0.084	0.038	0.093	0.150	0.084	0.150	0.093
				TOTAL	0.800	0.560	0.840	0.608
8706	0.049	0.141	0.069	0.142				
8707	0.078	0.169	0.097	0.162	summer 1987			
8708	0.084	0.121	0.072	0.139	0.211	0.431	0.238	0.443
8709	0.068	0.077	0.070	0.088				
8710	0.078	0.044	0.072	0.066	autumn 1987			
8711	0.122	0	0.105	0	0.269	0.121	0.247	0.154
8712	0.063	0	0.053	0				
8801	0.040	0	0.057	0	winter 1988			
8802	0.066	0	0.080	0	0.169	0	0.190	0
8803	0.026	0	0.026	0				
8804	0.086	0	0.069	0	spring 1988			
8805	0.060	0.121	0.069	0.146	0.172	0.121	0.164	0.146
				TOTAL	0.821	0.673	0.838	0.743
8806	0.032	0.156	0.047	0.182				
8807	0.047	0.147	0.064	0.163	summer 1988			
8808	0.048	0.127	0.088	0.138	0.128	0.430	0.199	0.483
8809	0.080	0.084	0.107	0.099				
8810	0.093	0.042	0.096	0.057	autumn 1988			
8811	0.069	0	0.088	0	0.242	0.126	0.291	0.156
8812	0.059	0	0.088	0				
8901	0.036	0	0.053	0	winter 1989			
8902	0.025	0	0.034	0	0.121	0	0.175	0
8903	0.059	0	0.039	0				
8904	0.043	0	0.046	0	spring 1989			
8905	0.094	0.079	0.094	0.135	0.196	0.079	0.178	0.135
				TOTAL	0.686	0.635	0.843	0.774

Table 15. Monthly, seasonal and annual changes in lake level and contributions of in lake storage to the hydrology budgets of Rice and Sturgeon Lakes for the hydrologic years 1986-87, 1987-88, 1988-89.

	Monthly Summary				Seasonal Summary			
Month	Rice Level (+/- cm)	Rice Storage (+/- cm)	Sturgeon Level (+/- cm)	Sturgeon Storage (m3 x E6)	Rice Level (+/- cm)	Rice Storage (+/- cm)	Sturgeon Level (+/- cm)	Sturgeon Storage (m3 x E6)
8606	−0.090	−9.09	−0.040	−1.88				
8607	−0.020	−2.02	0.010	0.47	summer 1986			
8608	−0.030	−3.03	−0.040	−1.88	−0.140	−14.14	−0.070	−3.30
8609	0.070	7.07	0.050	2.36				
8610	−0.130	−13.13	−0.090	−4.24	autumn 1986			
8611	0.040	4.04	0.010	0.47	−0.020	−2.02	−0.030	−1.41
8612	−0.010	−1.01	0.100	4.71				
8701	−0.040	−4.04	−0.310	−14.60	winter 1987			
8702	0.030	3.03	−0.190	−8.95	−0.020	−2.02	−0.400	−18.84
8703	0.050	5.05	0.300	14.13				
8704	0.060	6.06	0.120	5.65	spring 1987			
8705	−0.010	−1.01	0.070	3.30	0.100	10.10	0.490	23.08
				TOTAL	−0.080	−8.08	−0.010	−0.47
8706	−0.060	−6.06	−0.030	−1.41				
8707	0.000	0.00	0.000	0.00	summer 1987			
8708	0.050	5.05	−0.010	−0.47	−0.010	−1.01	−0.040	−1.88
8709	−0.020	−2.02	0.000	0.00				
8710	−0.040	−4.04	−0.010	−0.47	autumn 1987			
8711	0.000	0.00	0.020	0.94	−0.060	−6.06	0.010	0.47
8712	−0.030	−3.03	−0.030	−1.41				
8801	0.030	3.03	−0.150	−7.06	winter 1988			
8802	0.000	0.00	−0.140	−6.59	0	0	−0.320	−15.07
8803	0.020	2.02	0.190	8.95				
8804	0.100	10.10	0.130	6.12	spring 1988			
8805	−0.050	−5.05	0.000	0.00	0.070	7.07	0.320	15.07
				TOTAL	0	0	−0.030	−1.41
8806	−0.040	−4.04	−0.010	−0.47				
8807	0.000	0.00	0.030	1.41	summer 1988			
8808	0.020	2.02	−0.030	−1.41	−0.020	−2.02	−0.010	−0.47
8809	−0.010	−1.01	0.000	0.00				
8810	−0.070	−7.07	−0.030	−1.41	autumn 1988			
8811	0.000	0.00	−0.030	−1.41	−0.080	−8.08	−0.060	−2.83
8812	0.000	0.00	0.040	1.88				
8901	0.090	9.09	−0.220	−10.36	winter 1989			
8902	−0.030	−3.03	−0.130	−6.12	0.060	6.06	−0.310	−14.60
8903	0.210	21.21	0.500	23.55				
8904	−0.110	−11.11	−0.090	−4.24	spring 1989			
8905	−0.040	−4.04	−0.030	−1.41	0.060	6.06	0.380	17.90
				TOTAL	0.020	2.02	0	0

Table 16. Monthly balance of the Rice Lake hydrology budget for the 1986-87 hydrologic year.

Supply terms (m3 x E6)

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Bewdley North	0.25	0.13	0.14	0.18	0.16	0.15	0.19	0.14	0.11	0.24	0.23	0.12
Bewdley South	0.20	0.17	0.20	0.28	0.26	0.22	0.32	0.27	0.19	0.65	0.58	0.23
Ouse River	4.90	2.78	1.25	1.58	6.71	4.35	4.77	5.99	2.72	6.83	34.06	7.18
Indian River	7.58	4.79	4.52	6.59	8.15	6.30	5.52	4.38	5.07	10.83	15.76	4.85
Otonabee River	298	166	113	209	562	261	259	296	246	255	537	79.4
Ungauged	5.62	3.42	2.65	3.75	6.64	4.79	4.70	4.69	3.52	8.07	22.02	5.39
Precipitation	12.36	3.28	10.65	16.07	4.97	3.85	7.01	4.08	3.42	4.97	5.73	4.40
Total	329	181	132	237	588	281	282	316	261	287	615	102

Loss terms

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Trent River	252	103	138	330	545	220	263	303	211	290	518	75.0
Evaporation	12.32	12.57	12.49	6.60	4.19	0	0	0	0	0	0	8.47
Total	265	115	150	336	549	220	263	303	211	290	518	83.5

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Storage	-9.09	-2.02	-3.03	7.07	-13.1	4.04	-1.01	-4.04	3.03	5.05	6.05	-1.01
Balance(out-in + stor)	-73.4	-67.4	15.25	105.8	-52.8	-57.0	-20.2	-16.7	-46.6	8.569	-91.4	-19.1
% (out/in-stor)	78.3	63.1	111.3	145.9	91.2	79.4	92.8	94.7	81.9	103.0	85.0	81.3

Table 17. Monthly balance of the Rice Lake hydrology budget for the 1987-88 hydrologic year.

Supply terms (m3 x E6)

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Bewdley North	0.11	0.11	0.09	0.10	0.13	0.18	0.16	0.24	0.20	0.25	0.21	0.17
Bewdley South	0.20	0.18	0.15	0.15	0.16	0.18	0.26	0.42	0.27	1.90	0.29	0.18
Ouse River	2.82	1.31	0.42	0.31	0.68	1.83	6.13	5.84	5.29	4.40	25.13	10.00
Indian River	4.12	5.89	5.23	5.17	5.38	4.85	6.45	5.29	4.12	8.15	11.88	6.88
Otonabee River	74.4	56.1	50.2	41.6	50.0	125	257	319	298	239	427	295
Ungauged	3.15	3.26	2.56	2.49	2.76	3.06	5.65	5.13	4.30	6.39	16.32	7.50
Precipitation	4.99	7.85	8.49	6.90	7.87	12.36	6.35	4.06	6.69	2.65	8.73	6.02
Total	89.8	74.7	67.1	56.7	67.0	148	282	340	319	263	490	326

Loss terms

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Trent River	81.5	61.9	51.8	69.5	82.4	159.7	328.6	306.4	275.9	247.0	431.7	269.7
Evaporation	14.22	17.08	12.26	7.81	4.41	0	0	0	0	0	0	12.18
Total	95.8	79.0	64.0	77.3	86.8	160	329	306	276	247	432	282

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Storage	-6.06	0.00	5.05	-2.02	-4.04	0.00	-3.03	3.02	0.00	2.02	10.10	-5.05

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Balance(out-in+stor)	-0.1	4.3	1.9	18.6	15.8	12.1	43.9	-30.6	-43.3	-13.6	-48.2	-49.1
% (out/in-stor)	99.9	106	103	132	122	108	115	90.9	86.4	94.8	90.0	85.2

Table 18. Monthly balance of the Rice Lake hydrology budget for the 1988-89 hydrologic year.

Supply terms (m3 x E6)

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Bewdley North	0.13	0.08	0.10	0.12	0.13	0.12	0.15	0.18	0.12	0.25	0.16	0.17
Bewdley South	0.15	0.14	0.15	0.17	0.15	0.16	0.20	0.50	0.73	0.71	0.16	0.25
Ouse River	3.95	0.75	0.33	0.23	0.37	1.53	1.58	2.22	2.70	3.88	15.80	12.30
Indian River	5.66	6.47	5.55	6.46	5.85	5.72	3.11	3.66	2.98	9.32	10.52	10.28
Otonabee River	120	49.3	58.0	48.9	87.6	165	225	235	177	111	425	399
Ungauged	4.30	3.24	2.67	3.03	2.83	3.28	2.19	2.85	2.84	6.16	11.59	1.00
Precipitation	3.27	4.75	4.88	8.09	9.39	6.94	5.98	3.68	2.55	5.94	4.38	9.45
Total	138	64.7	71.7	67.0	106	182	238	248	189	137	468	432

Loss terms

Trent River	63.1	55.5	46.1	68.5	113.4	242.1	178.2	244.6	139.3	183.6	425.9	420.6
Evaporation	15.80	14.86	12.86	8.46	4.22	0	0	0	0	0	0	7.99
Total	78.9	70.3	59.0	76.9	117.6	242.1	178.2	244.6	139.3	183.6	425.9	428.6

Storage	-4.04	0.00	2.02	-1.01	-7.07	0.00	0.00	9.09	-3.03	21.21	-11.1	-4.04

Balance(out-in + stor)	-62.9	5.6	-10.7	8.9	4.2	59.8	-60.2	5.8	-52.5	68.1	-53.1	-7.9
% (out/in-stor)	55.6	108.6	84.6	113.1	103.7	132.8	74.7	102.4	72.6	158.9	88.9	98.2

Table 19. Seasonal balance of the Rice Lake hydrology budget for 1986-87,1987-88 and 1988-89.

Supply terms (m3 x E6)	1986-1987				1987-1988				1988-1989			
	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr
Bewdley North	0.51	0.49	0.45	0.59	0.32	0.41	0.59	0.63	0.31	0.37	0.45	0.57
Bewdley South	0.57	0.76	0.78	1.46	0.53	0.49	0.95	2.37	0.44	0.48	1.43	1.11
Ouse River	8.93	12.64	13.48	48.07	4.55	2.81	17.26	39.53	5.03	2.12	6.49	31.98
Indian River	16.90	21.04	14.97	31.44	15.23	15.39	15.86	26.92	17.68	18.03	9.76	30.13
Otonabee River	577	1031	801	872	181	217	874	962	228	301	637	935
Ungauged	11.70	15.19	12.91	35.48	8.97	8.31	15.07	30.21	10.20	9.14	7.88	27.75
Precipitation	26.29	24.88	14.51	15.10	21.33	27.13	17.10	17.39	12.90	24.42	12.20	19.78
Total	642	1106	858	1004	232	271	941	1079	274	356	675	1046
Loss terms												
Trent River	493	1093	776	883	195	312	911	948	165	424	562	1030
Evaporation	37.4	10.8	0.0	8.5	43.6	12.2	0.0	12.2	43.5	12.7	0.0	8.0
Total	530	1104	776	892	239	324	911	961	208	437	562	1038
Storage	-14.1	-2.0	-2.0	10.1	-1.0	-6.1	0.0	7.1	-2.0	-8.1	6.1	6.1
Balance(Out-In+Stor)	-126	-4.2	-83.6	-102	6.1	46.5	-29.9	-111	-68.1	72.8	-107	-2.0
% (Out/In-Storage)	80.8	99.6	90.3	89.7	103	117	96.8	89.7	75.4	120	84.0	99.8

Table 20. Annual balance of the Rice Lake hydrology budget for 1986-87,1987-88 and 1988-89.

Supply terms (m3 x E6)	1986-1987	1987-1988	1988-1989
Bewdley North	2.0	1.9	1.7
Bewdley South	3.6	4.3	3.5
Ouse River	83.1	64.2	45.6
Indian River	84.3	73.4	75.6
Otonabee River	3280	2233	2100
Unguaged	75	63	55
Precipitation	80.8	83.0	69.3
Total	3609	2522	2351
Loss terms			
Trent River Outflow	3246	2366	2181
Evaporation	56.6	68.0	64.2
Total	3302	2434	2245
Storage	-8.08	0	2.02
Balance(Out-In+Stor)	-314	-88.4	-103
% (Out/In-Storage)	91	97	96
Adjustment for 100% Balance	1.10	1.04	1.05

Table 21. Monthly, seasonal and annual water residence times in days for Rice and Sturgeon Lakes for the hydrologic years 1986-87, 1987-88 and 1988-89.

Monthly Summary

Month	Rice Residence (days)	Sturgeon Residence (days)		Rice Residence (days)	Sturgeon Residence (days)
8606	27.24	33.05			
8607	64.60	55.69	summer 1986		
8608	49.48	46.29		41.67	43.11
8609	21.43	24.79			
8610	13.57	15.25	autumn 1986		
8611	32.83	37.01		20.20	22.70
8612	28.36	38.06			
8701	24.59	34.61	winter 1987		
8702	31.87	43.41		28.46	39.07
8703	25.66	25.34			
8704	13.91	16.00	spring 1987		
8705	89.22	81.88		24.52	26.17
		TOTAL		26.55	30.37
8706	75.26	79.65			
8707	94.27	79.33	summer 1987		
8708	116.34	103.23		91.55	85.24
8709	93.24	114.65			
8710	85.77	109.01	autumn 1987		
8711	45.12	57.26		67.50	85.06
8712	22.66	28.14			
8801	24.30	33.78	winter 1988		
8802	24.38	30.64		23.73	30.68
8803	30.15	40.43			
8804	16.69	14.50	spring 1988		
8805	26.42	29.20		22.51	23.09
		TOTAL		36.12	40.82
8806	91.32	91.00			
8807	105.88	90.33	summer 1988		
8808	126.25	97.85		103.83	90.38
8809	93.65	78.62			
8810	63.31	112.63	autumn 1988		
8811	29.76	42.99		50.61	67.91
8812	41.79	53.35			
8901	30.44	53.50	winter 1989		
8902	48.28	104.30		39.31	64.39
8903	40.56	60.00			
8904	16.92	15.11	spring 1989		
8905	17.37	16.13		21.29	20.79
		TOTAL		39.05	44.53

Table 22. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures for the Big Bob Channel outlet (BB1) of Sturgeon Lake at Bobcaygeon (watershed area = 476,377 ha) for the hydrologic years 1986–87, 1987–88, 1988–89.

Monthly Summary

Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8606	0.144	157	0.032	22.1	31400
8607	0.050	94.7	0.019	38.3	16900
8608	0.101	114	0.023	22.8	24600
8609	0.178	214	0.043	24.2	19600
8610	0.042	363	0.073	174	68400
8611	0.036	146	0.029	82.8	48800
8612	0.061	147	0.030	48.6	32700
8701	0.050	161	0.033	65.7	51200
8702	0.028	116	0.023	83.8	38900
8703	0.063	220	0.044	70.2	38900
8704	0.049	337	0.068	140	29000
8705	0.038	63.8	0.013	34.1	14300
8706	0.069	61.1	0.012	18.0	19300
8707	0.097	62.7	0.013	13.0	19500
8708	0.072	47.5	0.010	13.4	14400
8709	0.070	42.9	0.009	12.4	9500
8710	0.072	48.1	0.010	13.5	14300
8711	0.105	94.3	0.019	18.2	29000
8712	0.053	198	0.040	76.3	47500
8801	0.057	165	0.033	58.2	48700
8802	0.080	165	0.033	41.3	45100
8803	0.026	138	0.028	107	33900
8804	0.069	372	0.075	109	78100
8805	0.069	184	0.037	53.9	47300
8806	0.047	50.8	0.010	21.3	9700
8807	0.064	54.1	0.011	17.1	14700
8808	0.088	50.5	0.010	11.6	14700
8809	0.107	64.0	0.013	12.1	14500
8810	0.096	46.8	0.009	9.9	13100
8811	0.088	126	0.025	28.9	15300
8812	0.088	105	0.021	24.0	33200
8901	0.053	104	0.021	39.5	26200
8902	0.034	48.3	0.010	29.1	14300
8903	0.039	93.0	0.019	48.7	14300
8904	0.046	357	0.072	158	53600
8905	0.094	340	0.069	73.4	58600

Seasonal Summary

Season	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
summer 1986	0.295	366	0.074	25.1	16900
autumn 1986	0.256	723	0.146	57.0	19600
winter 1987	0.139	424	0.086	61.8	32700
spring 1987	0.150	621	0.126	83.7	14300
TOTAL	**0.840**	**2135**	**0.431**	**51.3**	**14300**
summer 1987	0.237	171	0.035	14.6	14400
autumn 1987	0.246	185	0.037	15.2	9500
winter 1988	0.190	528	0.107	56.1	45100
spring 1988	0.164	695	0.140	85.6	33900
TOTAL	**0.838**	**1579**	**0.319**	**38.1**	**9500**
summer 1988	0.199	155	0.031	15.6	9700
autumn 1988	0.291	236	0.048	16.4	13100
winter 1989	0.175	257	0.052	29.7	14300
spring 1989	0.178	790	0.160	89.8	14300
TOTAL	**0.843**	**1439**	**0.291**	**34.5**	**9700**

Table 23. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures for the outlet of Cameron Lake to Sturgeon Lake at Fenelon Falls (CA1) (watershed area = 324,500 ha) for the hydrologic years 1986-87, 1987-88, 1988-89

Monthly Summary						Seasonal Summary					
Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)		Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8606	0.144	140	0.043	30.1	26630						
8607	0.050	111	0.034	68.2	30449	summer 1986					
8608	0.101	109	0.034	33.2	25189		0.295	360	0.111	37.6	25189
8609	0.178	143	0.044	24.6	16306						
8610	0.042	263	0.081	192	58342	autumn 1986					
8611	0.036	112	0.034	96.9	38187		0.256	517	0.159	62.2	16306
8612	0.061	107	0.033	53.9	29231						
8701	0.050	98.7	0.030	61.3	29653	winter 1987					
8702	0.028	74.2	0.023	81.7	19443		0.139	280	0.086	62.1	19443
8703	0.063	91.2	0.028	44.3	17839						
8704	0.049	190	0.058	120	21854	spring 1987					
8705	0.038	63.7	0.020	52.0	13718		0.150	345	0.106	70.9	13718
					TOTAL		0.840	1502	0.463	55.1	13718
8706	0.069	64.4	0.020	28.9	17523						
8707	0.097	66.2	0.020	21.0	16514	summer 1987					
8708	0.072	67.4	0.021	29.0	19496		0.237	198	0.061	25.7	16514
8709	0.070	58.0	0.018	25.6	10993						
8710	0.072	52.7	0.016	22.6	13224	autumn 1987					
8711	0.105	65.3	0.020	19.2	11727		0.246	176	0.054	22.0	10993
8712	0.053	129	0.040	76.0	35681						
8801	0.057	119	0.037	63.9	37842	winter 1988					
8802	0.080	109	0.033	41.6	32893		0.190	357	0.110	57.8	32893
8803	0.026	85.2	0.026	101	14812						
8804	0.069	291	0.090	130	52076	spring 1988					
8805	0.069	149	0.046	66.5	31612		0.164	525	0.162	98.7	14812
					TOTAL		0.838	1256	0.387	46.2	10993
8806	0.047	75.3	0.023	48.9	17690						
8807	0.064	78.8	0.024	37.9	23024	summer 1988					
8808	0.088	64.8	0.020	22.6	16703		0.199	219	0.067	33.7	16703
8809	0.107	65.8	0.020	19.0	15322						
8810	0.096	62.5	0.019	20.1	19099	autumn 1988					
8811	0.088	118	0.036	41.3	159884		0.291	246	0.076	26.1	15322
8812	0.088	98.2	0.030	34.3	27788						
8901	0.053	92.8	0.029	53.6	23618	winter 1989					
8902	0.034	44.0	0.014	40.3	13408		0.175	235	0.072	41.3	13408
8903	0.039	72.1	0.022	57.6	9848						
8904	0.046	250	0.077	168	57080	spring 1989					
8905	0.094	238	0.073	77.7	34388		0.178	561	0.173	97.2	9848
					TOTAL		0.843	1261	0.388	46.0	9848

Table 24. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures for the Martin Creek (MN1) subwatershed (area = 3473 ha) of Sturgeon Lake for the hydrologic years 1986-87, 1987-88, 1988-89.

Monthly Summary

Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8606	0.144	0.93	0.027	18.6	20
8607	0.050	0.22	0.006	12.8	33
8608	0.101	0.31	0.009	8.8	43
8609	0.178	2.28	0.066	36.7	116
8610	0.042	2.71	0.078	185	587
8611	0.036	1.28	0.037	103	378
8612	0.061	0.77	0.022	36.2	222
8701	0.050	0.68	0.019	39.3	198
8702	0.028	0.64	0.018	65.7	183
8703	0.063	3.08	0.089	140	470
8704	0.049	3.46	0.100	204	427
8705	0.038	0.74	0.021	56.5	161
8706	0.069	0.35	0.010	14.5	81
8707	0.097	0.26	0.007	7.6	59
8708	0.072	0.13	0.004	5.0	28
8709	0.070	0.08	0.002	3.4	18
8710	0.072	0.18	0.005	7.0	32
8711	0.105	0.49	0.014	13.4	97
8712	0.053	0.59	0.017	32.6	73
8801	0.057	1.00	0.029	50.5	159
8802	0.080	0.87	0.025	31.2	173
8803	0.026	1.30	0.037	143	159
8804	0.069	2.21	0.064	92.4	135
8805	0.069	1.35	0.039	56.5	109
8806	0.047	0.47	0.013	27.6	75
8807	0.064	0.11	0.003	5.1	18
8808	0.088	0.07	0.002	2.4	11
8809	0.107	0.24	0.007	6.5	26
8810	0.096	0.36	0.010	10.9	101
8811	0.088	1.04	0.030	34.1	143
8812	0.088	0.92	0.027	30.2	188
8901	0.053	0.72	0.021	38.8	173
8902	0.034	0.64	0.018	54.6	201
8903	0.039	2.36	0.068	176	253
8904	0.046	2.53	0.073	159	587
8905	0.094	2.75	0.079	84.0	412

Seasonal Summary

	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
summer 1986	0.295	3.74	0.042	14.2	20
autumn 1986	0.256	7.03	0.180	70.4	116
winter 1987	0.139	5.16	0.060	43.2	183
spring 1987	0.150	7.27	0.209	139.7	161
TOTAL	**0.840**	**17.08**	**0.492**	**58.5**	**20**
summer 1987	0.237	0.81	0.021	8.8	28
autumn 1987	0.246	1.34	0.021	8.7	18
winter 1988	0.190	3.77	0.071	37.4	73
spring 1988	0.164	4.86	0.140	85.3	109
TOTAL	**0.838**	**8.80**	**0.253**	**30.2**	**18**
summer 1988	0.199	0.89	0.019	9.5	11
autumn 1988	0.291	2.57	0.047	16.3	26
winter 1989	0.175	4.64	0.066	37.5	173
spring 1989	0.178	7.63	0.220	123.6	253
TOTAL	**0.843**	**12.21**	**0.351**	**41.6**	**11**

Table 25. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures for the Hawkers Creek (HK1) subwatershed (area = 4,433 ha) of Sturgeon Lake for the hydrologic years 1986-87, 1987-88, 1988-89.

Monthly Summary						Seasonal Summary					
Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)		Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8606	0.144	1.00	0.022	15.6	260						
8607	0.050	0.31	0.007	14.0	41	summer 1986					
8608	0.101	0.38	0.009	8.4	66		0.295	1.68	0.038	12.9	41
8609	0.178	3.51	0.079	44.4	181						
8610	0.042	3.73	0.084	199	667	autumn 1986					
8611	0.036	1.68	0.038	106	564		0.256	8.91	0.201	78.5	181
8612	0.061	1.44	0.033	53.4	469						
8701	0.050	1.13	0.026	51.6	372	winter 1987					
8702	0.028	1.14	0.026	91.8	321		0.139	3.72	0.084	60.5	3212
8703	0.063	4.00	0.090	142	458						
8704	0.049	4.16	0.094	193	287	spring 1987					
8705	0.038	0.59	0.013	35.1	140		0.150	8.74	0.197	131.6	140
					TOTAL		0.840	23.06	0.520	61.9	41

Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)		Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8706	0.069	0.34	0.008	11.2	81						
8707	0.097	0.36	0.008	8.4	40	summer 1987					
8708	0.072	0.09	0.002	2.8	6		0.237	0.79	0.018	7.5	6
8709	0.070	0.08	0.002	2.6	13						
8710	0.072	0.27	0.006	8.5	57	autumn 1987					
8711	0.105	0.70	0.016	15.0	126		0.246	1.05	0.024	9.6	13
8712	0.053	2.28	0.051	97.9	442						
8801	0.057	1.11	0.025	43.6	230	winter 1988					
8802	0.080	0.87	0.020	24.3	246		0.190	4.25	0.096	50.5	230
8803	0.026	2.15	0.048	186	207						
8804	0.069	3.72	0.084	122	657	spring 1988					
8805	0.069	1.36	0.031	44.3	218		0.164	7.22	0.163	99.4	207
					TOTAL		0.838	13.31	0.300	35.8	6

Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)		Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8806	0.047	0.23	0.005	10.6	38						
8807	0.064	0.08	0.002	2.9	12	summer 1988					
8808	0.088	0.02	0.000	0.6	0		0.199	0.33	0.008	4.0	0
8809	0.107	0.09	0.002	1.9	1						
8810	0.096	0.24	0.005	5.7	36	autumn 1988					
8811	0.088	1.18	0.027	30.2	205		0.291	1.51	0.034	11.7	1
8812	0.088	0.96	0.022	24.5	286						
8901	0.053	1.03	0.023	43.5	304	winter 1989					
8902	0.034	0.65	0.015	43.9	173		0.175	2.64	0.060	34.0	173
8903	0.039	2.90	0.065	169	164						
8904	0.046	4.49	0.101	221	451	spring 1989					
8905	0.094	4.43	0.100	106.4	456		0.178	11.82	0.267	150.0	164
					TOTAL		0.843	16.30	0.368	43.7	0

Table 26. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures for the Rutherford Creek (RD1) subwatershed (area = 1,823 ha) of Sturgeon Lake for the hydrologic years 1986-87, 1987-88, 1988-89.

Monthly Summary						Seasonal Summary					
Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)	Season	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8606	0.144	0.378	0.021	14.4	32						
8607	0.050	0.074	0.004	8.1	11	summer 1986					
8608	0.101	0.046	0.003	2.5	2		0.295	0.50	0.027	9.2	2
8609	0.178	0.582	0.032	17.9	13						
8610	0.042	0.510	0.028	66.3	89	autumn 1986					
8611	0.036	0.232	0.013	35.7	59		0.256	1.32	0.073	28.3	13
8612	0.061	0.242	0.013	21.8	59						
8701	0.050	0.145	0.008	16.1	28	winter 1987					
8702	0.028	0.061	0.003	11.9	8		0.139	0.45	0.025	17.7	8
8703	0.063	0.852	0.047	73.7	28						
8704	0.049	0.584	0.032	65.8	37	spring 1987					
8705	0.038	0.072	0.004	10.4	8		0.150	1.51	0.083	55.2	8
					TOTAL		0.840	3.78	0.207	24.7	2
8706	0.069	0.009	0	0.7	1						
8707	0.097	0.006	0	0.3	0	summer 1987					
8708	0.072	0.000	0	0.0	0		0.237	0.01	0.001	0.3	0
8709	0.070	0.003	0	0.2	0						
8710	0.072	0.014	0.001	1.1	1	autumn 1987					
8711	0.105	0.091	0.005	4.8	14		0.246	0.11	0.006	2.4	0
8712	0.053	0.363	0.020	38.0	49						
8801	0.057	0.242	0.013	23.2	17	winter 1988					
8802	0.080	0.232	0.013	15.8	15		0.190	0.84	0.046	24.1	15
8803	0.026	0.632	0.035	132.9	16						
8804	0.069	0.588	0.032	46.9	81	spring 1988					
8805	0.069	0.318	0.017	25.3	42		0.164	1.54	0.084	51.5	16
					TOTAL		0.838	2.50	0.137	16.4	0
8806	0.047	0.094	0.005	10.6	24						
8807	0.064	0.048	0.003	4.1	0	summer 1988					
8808	0.088	0.043	0.002	2.7	0		0.199	0.19	0.010	5.0	0
8809	0.107	0.023	0.001	1.2	0						
8810	0.096	0.012	0.001	0.7	1	autumn 1988					
8811	0.088	0.140	0.008	8.7	6		0.291	0.18	0.010	3.3	0
8812	0.088	0.139	0.008	8.7	19						
8901	0.053	0.154	0.008	15.8	27	winter 1989					
8902	0.034	0.040	0.002	6.6	4		0.175	0.33	0.018	10.4	4
8903	0.039	0.547	0.030	77.8	0						
8904	0.046	0.594	0.033	71.2	51	spring 1989					
8905	0.094	0.601	0.033	35.1	48		0.178	1.74	0.096	53.9	0
					TOTAL		0.843	2.44	0.134	15.9	0

Table 27. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures for the McLaren Creek (ML1) subwatershed (area = 5,339 ha) of Sturgeon Lake for the hydrologic years 1986-87, 1987-88, 1988-89

	Monthly Summary					Seasonal Summary				
Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8606	0.144	1.77	0.033	23.1	73					
8607	0.050	0.36	0.007	13.6	29	summer 1986				
8608	0.101	0.56	0.010	10.3	3	0.295	2.69	0.050	17.1	3
8609	0.178	3.21	0.060	33.7	121					
8610	0.042	3.67	0.069	163	777	autumn 1986				
8611	0.036	1.25	0.023	65.7	194	0.256	8.12	0.152	59.4	121
8612	0.061	0.96	0.018	29.4	119					
8701	0.050	0.98	0.018	37.1	197	winter 1987				
8702	0.028	1.08	0.020	72.3	97	0.139	3.02	0.057	40.8	97
8703	0.063	7.11	0.133	210	637					
8704	0.049	3.53	0.066	136	219	spring 1987				
8705	0.038	0.45	0.008	22.2	81	0.150	11.09	0.208	138.5	81
					TOTAL	0.840	24.92	0.467	55.6	3
8706	0.069	0.10	0.002	2.7	0					
8707	0.097	0.01	0.000	0.3	0	summer 1987				
8708	0.072	0.00	0.000	0.0	0	0.237	0.11	0.002	0.9	0
8709	0.070	0.00	0.000	0.0	0					
8710	0.072	0.07	0.001	1.8	0	autumn 1987				
8711	0.105	0.58	0.011	10.4	77	0.246	0.65	0.012	4.9	0
8712	0.053	2.32	0.044	82.9	268					
8801	0.057	1.71	0.032	55.9	183	winter 1988				
8802	0.080	2.03	0.038	47.2	414	0.190	6.06	0.113	59.6	183
8803	0.026	3.48	0.065	250	296					
8804	0.069	2.49	0.047	67.7	369	spring 1988				
8805	0.069	1.25	0.023	33.8	190	0.164	7.21	0.135	82.4	190
					TOTAL	0.838	14.03	0.263	31.4	0
8806	0.047	0.13	0.002	4.3	0					
8807	0.064	0	0	0	0	summer 1988				
8808	0.088	0.01	0	0.1	0	0.199	0.14	0.003	1.5	0
8809	0.107	0.05	0.001	0.9	0					
8810	0.096	0.39	0.007	7.7	42	autumn 1988				
8811	0.088	1.86	0.035	39.6	179	0.291	2.30	0.043	14.8	0
8812	0.088	1.35	0.025	28.6	240					
8901	0.053	1.46	0.027	51.2	241	winter 1989				
8902	0.034	0.82	0.015	45.8	113	0.175	3.63	0.068	38.8	113
8903	0.039	2.11	0.040	102	60					
8904	0.046	2.03	0.038	83.0	308	spring 1989				
8905	0.094	2.39	0.045	47.8	240	0.178	6.53	0.122	68.5	60
					TOTAL	0.843	12.60	0.236	28.0	0

Table 28. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures for the Emily Creek at Downeyville (EAD) subwatershed (area = 2,772 ha) of Sturgeon Lake for the hydrologic years 1986-87, 1987-88, 1988-89.

Monthly Summary

Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8606	0.144	0.355	0.013	8.9	37
8607	0.050	0.075	0.003	5.4	12
8608	0.101	0.061	0.002	2.2	14
8609	0.178	0.372	0.013	7.5	12
8610	0.042	0.640	0.023	54.8	101
8611	0.036	0.333	0.012	33.7	73
8612	0.061	0.092	0.003	5.4	16
8701	0.050	0.065	0.002	4.8	16
8702	0.028	0.067	0.002	8.6	20
8703	0.063	2.05	0.074	117	54
8704	0.049	1.353	0.049	100	37
8705	0.038	0.097	0.003	9.2	22
8706	0.069	0.073	0.003	3.8	13
8707	0.097	0.040	0.001	1.5	8
8708	0.072	0.036	0.001	1.8	6
8709	0.070	0.038	0.001	2.0	10
8710	0.072	0.082	0.003	4.1	10
8711	0.105	0.371	0.013	12.8	67
8712	0.053	1.14	0.041	78.1	154
8801	0.057	0.558	0.020	35.1	67
8802	0.080	0.957	0.035	42.9	133
8803	0.026	3.37	0.122	466	98
8804	0.069	0.779	0.028	40.9	3
8805	0.069	0.700	0.025	36.6	47
8806	0.047	0.114	0.004	8.5	12
8807	0.064	0.025	0.001	1.4	5
8808	0.088	0.027	0.001	1.1	5
8809	0.107	0.046	0.002	1.6	8
8810	0.096	0.059	0.002	2.2	17
8811	0.088	0.154	0.006	6.3	21
8812	0.088	0.155	0.006	6.4	31
8901	0.053	0.197	0.007	13.3	46
8902	0.034	0.180	0.006	19.3	55
8903	0.039	1.25	0.045	116	53
8904	0.046	1.20	0.043	94.5	236
8905	0.094	1.16	0.042	44.7	102

Seasonal Summary

Season	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
summer 1986	0.295	0.49	0.018	6.0	12
autumn 1986	0.256	1.35	0.049	18.9	12
winter 1987	0.139	0.22	0.008	5.8	16
spring 1987	0.150	3.50	0.126	84.2	22
TOTAL	0.840	5.56	0.201	23.9	12
summer 1987	0.237	0.15	0.005	2.3	6
autumn 1987	0.246	0.49	0.018	7.2	10
winter 1988	0.190	2.65	0.096	50.3	67
spring 1988	0.164	4.85	0.175	106.7	3
TOTAL	0.838	8.14	0.294	35.0	3
summer 1988	0.199	0.17	0.006	3.0	5
autumn 1988	0.291	0.26	0.009	3.2	8
winter 1989	0.175	0.53	0.019	11.0	31
spring 1989	0.178	3.61	0.130	73.0	53
TOTAL	0.843	4.57	0.165	19.6	5

Table 29. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures for the Dunsford Creek (DD1) subwatershed (area = 2,439 ha) of Sturgeon Lake for the hydrologic years 1986-87, 1987-88, 1988-89.

Monthly Summary						Seasonal Summary				
Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8606	0.144	0.832	0.034	23.7	71					
8607	0.050	0.126	0.005	10.3	6	summer 1986				
8608	0.101	0.090	0.004	3.6	11	0.295	1.05	0.043	14.5	6
8609	0.178	0.763	0.031	17.5	7					
8610	0.042	1.511	0.062	147	197	autumn 1986				
8611	0.036	0.447	0.018	51.5	109	0.256	2.72	0.112	43.5	7
8612	0.061	0.340	0.014	22.8	64					
8701	0.050	0.246	0.010	20.4	56	winter 1987				
8702	0.028	0.139	0.006	20.3	35	0.139	0.72	0.030	21.4	35
8703	0.063	3.202	0.131	207	41					
8704	0.049	2.196	0.090	185	101	spring 1987				
8705	0.038	0.103	0.004	11.2	16	0.150	5.50	0.226	150.5	16
					TOTAL	0.840	9.99	0.410	48.8	6
8706	0.069	0.017	0.001	1.01	2					
8707	0.097	0.026	0.001	1.11	1	summer 1987				
8708	0.072	0.011	0.000	0.66	3	0.237	0.05	0.002	0.9	1
8709	0.070	0.007	0.000	0.44	2					
8710	0.072	0.011	0.000	0.65	2	autumn 1987				
8711	0.105	0.044	0.002	1.72	8	0.246	0.06	0.003	1.0	2
8712	0.053	0.558	0.023	43.5	36					
8801	0.057	0.274	0.011	19.6	22	winter 1988				
8802	0.080	0.374	0.015	19.1	62	0.190	1.21	0.049	26.0	22
8803	0.026	1.509	0.062	237	44					
8804	0.069	2.030	0.083	121	293	spring 1988				
8805	0.069	0.395	0.016	23.5	38	0.164	3.93	0.161	98.4	38
					TOTAL	0.838	5.26	0.216	25.7	1
8806	0.047	0.069	0.003	6.40	8					
8807	0.064	0.006	0.000	0.36	0	summer 1988				
8808	0.088	0.020	0.001	0.93	1	0.199	0.09	0.004	2.0	0
8809	0.107	0.033	0.001	1.26	1					
8810	0.096	0.039	0.002	1.66	3	autumn 1988				
8811	0.088	0.504	0.021	23.54	18	0.291	0.58	0.024	8.1	1
8812	0.088	0.300	0.012	13.93	42					
8901	0.053	0.252	0.010	19.34	72	winter 1989				
8902	0.034	0.163	0.007	19.94	16	0.175	0.72	0.029	16.7	16
8903	0.039	2.541	0.104	270	9					
8904	0.046	2.714	0.111	243	139	spring 1989				
8905	0.094	2.445	0.100	106.4	127	0.178	7.70	0.316	177.5	9
					TOTAL	0.843	9.09	0.373	44.2	0

Table 30. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures estimated for the Emily Creek (EY1) subwatershed (area = 16,697 ha) of Sturgeon Lake for the hydrologic years 1986-87, 1987-88, 1988-89.

Monthly Summary

Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8606	0.144	3.80	0.023	15.8	346
8607	0.050	0.64	0.004	7.68	57
8608	0.101	0.48	0.003	2.84	80
8609	0.178	3.63	0.022	12.2	87
8610	0.042	6.90	0.041	97.9	1025
8611	0.036	2.50	0.015	42.1	658
8612	0.061	1.38	0.008	13.6	276
8701	0.050	1.00	0.006	12.1	241
8702	0.028	0.66	0.004	14.1	199
8703	0.063	16.83	0.101	159	303
8704	0.049	11.37	0.068	140	497
8705	0.038	0.64	0.004	10.1	139
8706	0.069	0.29	0.002	2.50	49
8707	0.097	0.21	0.001	1.32	42
8708	0.072	0.15	0.001	1.27	29
8709	0.070	0.15	0.001	1.26	40
8710	0.072	0.30	0.002	2.48	41
8711	0.105	1.33	0.008	7.61	243
8712	0.053	5.43	0.033	61.9	613
8801	0.057	2.66	0.016	27.8	293
8802	0.080	4.26	0.026	31.8	625
8803	0.026	15.63	0.094	359	465
8804	0.069	9.00	0.054	78.4	1118
8805	0.069	3.51	0.021	30.4	271
8806	0.047	0.59	0.004	8.50	68
8807	0.064	0.10	0.001	0.91	17
8808	0.088	0.15	0.001	1.02	22
8809	0.107	0.25	0.002	1.42	28
8810	0.096	0.31	0.002	1.96	66
8811	0.088	2.11	0.013	14.37	126
8812	0.088	1.46	0.009	9.90	284
8901	0.053	1.44	0.009	16.1	408
8902	0.034	1.10	0.007	19.6	227
8903	0.039	12.13	0.073	188.2	207
8904	0.046	12.54	0.075	164.0	1246
8905	0.094	11.57	0.069	73.4	1508

Seasonal Summary

Season	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
summer 1986	0.295	4.93	0.030	10.0	57
autumn 1986	0.256	13.03	0.078	30.5	87
winter 1987	0.139	3.04	0.018	13.1	199
spring 1987	0.150	28.84	0.173	115.2	139
TOTAL	**0.840**	**49.84**	**0.298**	**35.5**	**57**
summer 1987	0.237	0.65	0.004	1.6	29
autumn 1987	0.246	1.78	0.011	4.3	40
winter 1988	0.190	12.36	0.074	38.9	293
spring 1988	0.164	28.14	0.169	102.8	271
TOTAL	**0.838**	**42.93**	**0.257**	**30.7**	**29**
summer 1988	0.199	0.84	0.005	2.5	17
autumn 1988	0.291	2.68	0.016	5.5	28
winter 1989	0.175	4.00	0.024	13.7	284
spring 1989	0.178	36.24	0.217	121.9	207
TOTAL	**0.843**	**43.75**	**0.262**	**31.1**	**17**

Table 31. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures estimated for the Scugog River (SGW) subwatershed (area = 96,370 ha) of Sturgeon Lake for the hydrologic years 1986-87, 1987-88, 1988-89

Monthly Summary						Seasonal Summary					
Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)		Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)	Baseflow (L/s)
8606	0.144	13.3	0.013	9.07	380						
8607	0.050	8.24	0.008	16.2	490	summer 1986					
8608	0.101	18.3	0.018	17.7	500		0.295	39.87	0.039	13.3	380
8609	0.178	29.6	0.029	16.3	380						
8610	0.042	54.3	0.053	126	5330	autumn 1986					
8611	0.036	14.2	0.014	39.1	5000		0.256	98.08	0.096	37.6	380
8612	0.061	22.1	0.022	35.6	4520						
8701	0.050	28.7	0.028	56.8	7950	winter 1987					
8702	0.028	12.0	0.012	42.0	3090		0.139	62.78	0.062	44.5	3090
8703	0.063	41.6	0.041	64.4	3710						
8704	0.049	48.9	0.048	98.6	750	spring 1987					
8705	0.038	2.67	0.003	6.92	380		0.150	93.19	0.091	61.0	380
					TOTAL		0.840	293.91	0.288	34.3	380
8706	0.069	3.75	0.004	5.37	480						
8707	0.097	8.97	0.009	9.05	760	summer 1987					
8708	0.072	4.19	0.004	5.75	470		0.237	16.92	0.017	7.0	470
8709	0.070	2.62	0.003	3.68	580						
8710	0.072	6.60	0.006	8.99	600	autumn 1987					
8711	0.105	33.3	0.033	31.2	10200		0.246	42.48	0.042	16.9	580
8712	0.053	44.7	0.044	83.6	11900						
8801	0.057	21.3	0.021	36.4	1600	winter 1988					
8802	0.080	23.9	0.023	29.1	3420		0.190	89.86	0.088	46.4	1600
8803	0.026	15.6	0.015	58.7	2620						
8804	0.069	28.8	0.028	41.0	4820	spring 1988					
8805	0.069	11.8	0.012	16.8	2140		0.164	56.15	0.055	33.6	2140
					TOTAL		0.838	205.40	0.202	24.1	470
8806	0.047	1.94	0.002	4.30	610						
8807	0.064	2.20	0.002	3.37	660	summer 1988					
8808	0.088	2.01	0.002	2.23	630		0.199	6.15	0.006	3.0	610
8809	0.107	1.70	0.002	1.56	580						
8810	0.096	1.39	0.001	1.42	160	autumn 1988					
8811	0.088	21.8	0.021	24.3	160		0.291	24.86	0.024	8.4	160
8812	0.088	8.34	0.008	9.28	2430						
8901	0.053	13.8	0.014	25.3	3530	winter 1989					
8902	0.034	10.3	0.010	30.1	3520		0.175	32.42	0.032	18.2	2430
8903	0.039	18.1	0.018	45.9	3400						
8904	0.046	20.3	0.020	43.5	1310	spring 1989					
8905	0.094	30.8	0.030	31.9	3520		0.178	69.19	0.068	38.2	1310
					TOTAL		0.843	132.62	0.130	15.4	160

Table 32. Monthly, seasonal and annual discharge, areal runoff, % yield and baseflow figures for the unguaged portion of the Sturgeon Lake watershed (UNG) (area = 19,032 ha) for the hydrologic years 1986-87, 1987-88, 1988-89.

Monthly Summary

Month	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)
8606	0.144	4.94	0.026	18.0
8607	0.050	1.10	0.006	11.5
8608	0.101	1.35	0.007	7.0
8609	0.178	10.05	0.053	29.6
8610	0.042	11.98	0.063	149
8611	0.036	4.90	0.026	72.3
8612	0.061	3.60	0.019	31.0
8701	0.050	3.05	0.016	32.3
8702	0.028	2.93	0.015	55.0
8703	0.063	19.04	0.100	158
8704	0.049	14.33	0.075	155
8705	0.038	1.92	0.010	26.7
8706	0.069	0.83	0.004	6.36
8707	0.097	0.66	0.003	3.56
8708	0.072	0.25	0.001	1.80
8709	0.070	0.20	0.001	1.48
8710	0.072	0.59	0.003	4.27
8711	0.105	2.13	0.011	10.7
8712	0.053	6.81	0.036	68.2
8801	0.057	4.59	0.024	42.1
8802	0.080	5.00	0.026	32.7
8803	0.026	11.67	0.061	235.0
8804	0.069	11.08	0.058	84.6
8805	0.069	5.04	0.026	38.4
8806	0.047	1.04	0.005	11.7
8807	0.064	0.26	0.001	2.12
8808	0.088	0.18	0.001	1.07
8809	0.107	0.46	0.002	2.24
8810	0.096	1.04	0.005	5.68
8811	0.088	4.57	0.024	27.4
8812	0.088	3.59	0.019	21.4
8901	0.053	3.58	0.019	35.2
8902	0.034	2.34	0.012	36.6
8903	0.039	10.99	0.058	149.5
8904	0.046	12.72	0.067	145.9
8905	0.094	12.92	0.068	72.5

Seasonal Summary

	Precip (m)	Discharge (m3 x E6)	Areal ro (m)	Yield (%)
summer 1986	0.295	7.39	0.039	13.1
autumn 1986	0.256	26.92	0.141	55.2
winter 1987	0.139	9.58	0.050	36.3
spring 1987	0.150	35.30	0.185	123.7
TOTAL	**0.840**	**79.19**	**0.416**	**49.5**
summer 1987	0.237	1.73	0.009	3.8
autumn 1987	0.246	2.91	0.015	6.2
winter 1988	0.190	16.40	0.086	45.3
spring 1988	0.164	27.79	0.146	89.1
TOTAL	**0.838**	**49.88**	**0.257**	**30.6**
summer 1988	0.199	1.47	0.008	3.9
autumn 1988	0.291	6.07	0.032	11.0
winter 1989	0.175	9.51	0.050	28.5
spring 1989	0.178	36.63	0.192	108.1
TOTAL	**0.843**	**52.64**	**0.282**	**33.5**

ble 33. Monthly balance of the Sturgeon Lake hydrology budget for the 1986-87hydrologic year

ipply terms (m3 x E6)

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
lartin	0.93	0.22	0.31	2.28	2.71	1.28	0.77	0.68	0.64	3.08	3.46	0.74
awkers	1.00	0.31	0.38	3.51	3.73	1.68	1.44	1.13	1.14	4.00	4.16	0.59
utherford	0.38	0.07	0.05	0.58	0.51	0.23	0.24	0.15	0.06	0.85	0.58	0.07
unsford	0.83	0.13	0.09	0.76	1.51	0.45	0.34	0.25	0.14	3.20	2.20	0.10
mily at Downeyville	0.35	0.07	0.06	0.37	0.64	0.33	0.09	0.07	0.07	2.05	1.35	0.10
mily	3.80	0.64	0.48	3.63	6.89	2.50	1.38	1.00	0.66	16.83	11.37	0.64
IcLaren	1.77	0.36	0.56	3.21	3.67	1.25	0.96	0.98	1.08	7.11	3.53	0.45
cugog River	13.3	8.2	18.3	29.6	54.3	14.2	22.1	28.7	12.0	41.6	48.9	2.7
enelon Falls	140	111	109	143	263	112	107	99	74	91	190	64
Ingauged	4.94	1.10	1.35	10.05	11.98	4.90	3.60	3.05	2.93	19.04	14.34	1.92
recipitation	6.77	2.36	4.78	8.40	1.99	1.68	2.87	2.34	1.32	2.99	2.29	1.78
'OTAL *	173	124	136	204	349	140	140	137	94	187	278	73

*Total does not include Dunsford Creek or Emily at Downeyville.
These were included in Emily Creek figure

oss terms

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
ig Bob Channel	157	95	114	214	363	146	147	161	116	220	337	64
vaporation	6.21	5.52	6.14	3.70	2.67	0	0	0	0	0	0	4.39
'OTAL	163	100	121	218	366	146	147	161	116	220	337	68

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
itorage	-1.88	0.471	-1.88	2.355	-4.23	0.470	4.71	-14.6	-8.95	14.13	5.65	3.29

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Balance(out-in+stor)	-11.6	-23.2	-17.0	16.4	12.9	6.8	11.3	9.9	13.1	47.6	64.7	-1.2
% (out/in-stor)	93.3	81.2	87.7	108.2	103.7	104.9	108.4	106.5	112.7	127.6	123.7	98.3

Table 34. Monthly balance of the Sturgeon Lake hydrology budget for the 1987-88 hydrologic year.

Supply terms (m3 x E6)

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Martin	0.35	0.26	0.13	0.08	0.18	0.49	0.59	1.00	0.87	1.30	2.21	1.35
Hawkers	0.34	0.36	0.09	0.08	0.27	0.70	2.28	1.11	0.87	2.15	3.72	1.36
Rutherford	0.01	0.01	0	0	0.01	0.09	0.36	0.24	0.23	0.63	0.59	0.32
Dunsford	0.02	0.03	0.01	0.01	0.01	0.04	0.56	0.27	0.37	1.51	2.03	0.39
Emily at Downeyville	0.07	0.04	0.04	0.04	0.08	0.37	1.14	0.56	0.96	3.37	0.78	0.70
Emily	0.29	0.21	0.15	0.15	0.30	1.33	5.43	2.66	4.26	15.63	9.00	3.51
McLaren	0.10	0.01	0	0	0.07	0.58	2.32	1.71	2.03	3.48	2.49	1.25
Scugog River	3.75	8.97	4.19	2.62	6.59	33.3	44.7	21.3	23.9	15.6	28.8	11.8
Fenelon Falls	64.4	66.2	67.4	58.0	52.7	65.3	129	119	109	85.2	291	149
Ungauged	0.83	0.66	0.25	0.20	0.59	2.13	6.81	4.59	5.00	11.67	11.08	5.04
Precipitation	3.23	4.58	3.37	3.29	3.39	4.93	2.47	2.70	3.79	1.23	3.24	3.25
TOTAL *	73.3	81.3	75.6	64.4	64.1	109	194	154	149	137	352	177

*Total does not include Dunsford Creek or Emily at Downeyville.
These were included in Emily Creek figure

Loss terms

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Big Bob Channel	61.1	62.7	47.5	42.9	48.1	94.3	198	165	165	138	372	184
Evaporation	6.69	7.63	6.53	4.16	3.12	0	0	0	0	0	0	6.883
TOTAL	67.8	70.3	54.1	47.1	51.2	94.3	198	165	165	138	372	191

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Storage	-1.42	0	-0.47	0	-0.47	0.941	-1.41	-7.06	-6.59	8.95	6.12	0

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Balance(out-in+stor)	-6.91	-10.9	-22.0	-17.2	-13.4	-13.5	2.490	4.045	8.518	10.07	26.35	14.40
% (out/in-stor)	90.7	86.5	71.1	73.2	79.2	87.4	101.3	102.5	105.5	107.9	107.6	108.2

able 35. Monthly balance of the Sturgeon Lake hydrology budget for the 1988-89 hydrologic year.

upply terms (m3 x E6)

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
lartin	0.47	0.11	0.07	0.24	0.36	1.04	0.92	0.72	0.64	2.36	2.53	2.75
lawkers	0.23	0.08	0.02	0.09	0.24	1.18	0.96	1.03	0.65	2.90	4.49	4.43
utherford	0.09	0.05	0.04	0.02	0.01	0.14	0.14	0.15	0.04	0.55	0.59	0.60
unsford	0.07	0.01	0.02	0.03	0.04	0.50	0.30	0.25	0.16	2.54	2.71	2.45
mily at Downeyville	0.11	0.02	0.03	0.05	0.06	0.15	0.16	0.20	0.18	1.25	1.20	1.16
mily	0.59	0.10	0.15	0.25	0.31	2.11	1.46	1.44	1.10	12.13	12.54	11.57
lcLaren	0.13	0.00	0.01	0.05	0.39	1.86	1.35	1.46	0.82	2.11	2.03	2.39
cugog River	1.94	2.20	2.01	1.70	1.39	21.77	8.34	13.76	10.32	18.05	20.30	30.84
enelon Falls	75.3	78.8	64.8	65.8	62.5	118	98.2	92.8	44.0	72.1	250.2	238.3
Jngauged	1.06	0.26	0.18	0.46	1.04	4.57	3.59	3.58	2.34	10.98	12.72	12.92
recipitation	2.19	3.02	4.16	5.03	4.52	4.14	4.15	2.52	1.58	1.82	2.16	4.41
OTAL *	82.0	84.6	71.5	73.7	70.8	154	119	117	61.5	123	308	308

*Total does not include Dunsford Creek or Emily at Downeyville. These were included in the Emily Creek figure

oss terms

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
ig Bob Channel	50.8	54.1	50.5	64.0	46.8	126	105	104	48.3	93.0	357	340
vaporation	8.59	7.65	6.50	4.64	2.70	0	0	0	0	0	0	6.35
OTAL	59.3	61.8	57.0	68.7	49.5	126	105	104	48.32	93.01	357	346

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Storage	-0.47	1.41	-1.41	0.00	-1.41	-1.41	1.88	-10.4	-6.12	23.55	-4.23	-1.41

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Balance(out-in+stor)	-23.1	-21.4	-15.8	-5.0	-22.7	-30.3	-12.6	-23.5	-19.3	-6.4	45.6	36.3
% (out/in-stor)	71.9	74.3	78.3	93.2	68.6	80.6	89.2	81.6	71.5	93.5	114.6	111.7

Table 36. Seasonal balance of the Sturgeon Lake hydrology budget for 1986–1987, 1987–1989 and 1988–1989.

Supply terms (m3 x 10E6)

	1986–1987				1987–1988				1988–1989			
	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr
Martin	1.46	6.25	2.08	7.27	0.73	0.74	2.47	4.86	0.65	1.64	2.28	7.63
Hawkers	1.68	8.91	3.72	8.74	0.79	1.05	4.25	7.22	0.33	1.51	2.64	11.82
Rutherford	0.50	1.32	0.45	1.51	0.01	0.11	0.84	1.54	0.19	0.18	0.33	1.74
Dunsford	1.05	2.72	0.72	5.50	0.05	0.06	1.21	3.93	0.09	0.58	0.72	7.70
Emily at Downeyville	0.49	1.35	0.22	3.50	0.15	0.49	2.65	4.85	0.17	0.26	0.53	3.61
Emily	4.92	13.03	3.04	28.84	0.65	1.78	12.36	28.14	0.84	2.67	3.99	36.24
McLaren	2.69	8.12	3.02	11.09	0.11	0.65	6.06	7.21	0.14	2.30	3.36	6.53
Scugog River	39.87	98.08	62.78	93.19	16.92	42.48	89.87	56.15	6.15	24.86	32.42	69.19
Fenelon Falls	360.3	517.3	279.5	344.7	198.1	176.0	356.7	525.1	218.9	246.0	235.0	560.6
Ungauged	7.39	25.80	9.53	33.28	2.06	2.69	14.12	25.73	1.82	9.11	13.56	36.63
Precipitation	13.90	12.07	6.53	7.06	11.18	11.61	8.96	7.72	9.37	13.69	8.25	8.38
TOTAL *	432.7	690.8	370.6	535.6	230.5	237.1	495.6	663.6	238.3	301,9	301.8	738.7

*Total does not include Dunsford Creek or Emily at Downeyville.

Loss terms

	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr
Big Bob Channel	366.3	723.2	423.9	621.4	171.3	185.3	528.0	694.6	155.4	236.5	257.2	790.0
Evaporation	17.87	6.37	0.00	4.39	20.86	7.27	0.00	6.88	22.74	7.35	0.00	6.35
TOTAL	384.2	729.6	423.9	625.8	192.2	192.6	528.0	701.5	178.1	243.8	257.2	796.4

Storage	–3.3	–1.4	–18.8	23.1	–1.9	0.5	–14.6	15.1	–0.5	–2.8	–14.6	17.9

Balance(out–in+stor)	–51.8	37.3	34.4	113.2	–40.3	–44.1	17.8	52.9	–60.7	–60.9	–59.2	75.5
% (out/in-stor)	88.1	105.4	108.8	122.1	82.7	81.4	103.5	108.2	74.6	80.0	81.3	110.5

Table 37. Annual balance of the Sturgeon Lake hydrology budget for 1986–1987, 1987–1988 and 1988–1989.

<u>Supply terms</u> (m3 x E6)

	1986–1987	1987–1988	1988–1989
Martin	17.08	8.8	12.21
Hawkers	23.06	13.31	16.3
Rutherford	3.78	2.5	2.44
Dunsford	9.99	5.26	9.09
Emily at Downeyville	5.56	8.14	4.57
Emily	49.84	42.93	43.75
McLaren	24.92	14.03	12.6
Scugog River	293.9	205.4	132.6
Fenelon Falls	1501	1256	1261
Ungauged	79.92	48.83	53.68
Precipitation	39.56	39.47	39.7
TOTAL *	2033.06	1631.27	1574.28

*Total does not include Dunsford Creek or Emily at Downeyville. These were included in Emily Creek figure.

<u>Loss terms</u>

Big Bob Channel	2135	1579	1439
Evaporation	28.64	35.02	36.44
TOTAL	2163.64	1614.02	1475.44
Storage	–0.471	–0.942	0
Balance(out–in+stor)	130.109	–18.192	–98.84
% (out/in-stor)	6.0	–1.1	–6.7
Adjustment for 100% balance	0.939	1.011	1.067

Table 38. Land use characteristics of Rice and Sturgeon Lake sub-watersheds.

Rice Lake Sub–Watershed Land Use

	Area (ha)	Agriculture (Percent of Total)	Wooded		Marsh	Urban
			Dry	Wet		
Bewdley North	631	47	53	0	0	0
Bewdley South	2220	93	7	0	0	0
Indian River	25800	69	8	14	6	3
Ouse River	28200	52	9	36	2	1

Sturgeon Lake Sub–Watershed Land Use

	Area (ha)	Agriculture (Percent of Total)	Wooded		Marsh	Urban	
			Dry	Wet			
Emily (Downeyville)	2772	71	16	9	3	1	
Dunsford Creek	2439	67	7	24	1	1	
Emily Creek	16697	64	14	16	2	1	(1% lake, 2% river)
Martin Creek	3473	34	56	10	0	0	
Hawkers Creek	4433	53	36	10	1	0	
Rutherford Creek	1823	51	42	7	0	0	
McLaren Creek	5339	77	7	12	1	1	(2% lake)

Table 39. Relationship between land use characteristics and seasonal and annual water yield for Rice and Sturgeon Lake sub-watersheds.
Coefficients of determination (r2) and significance level (p) are given for each added variable (var) in a stepwise multiple regression model. dw=dry woodland, ww=wet woodland, ag=agricultural, ur=urban, ma=marsh.

	Step 1			Step 2			Step 3			Step 4			Step 5		
Period	var	r2	p	var	r2	p	var	r2	p	var	r2	p	var	r2	p
Autumn	dw	0.19	0.18	ur	0.29	0.26	ma	0.32	0.41						
Winter	ww	0.15	0.24	ag	0.17	0.46									
Spring	ww	0.13	0.28	ur	0.15	0.53									
Summer	ma	0.10	0.22	dw	0.32	0.21	ur	0.40	0.28	ag	0.49	0.32			
86-87	ag	0.19	0.19	dw	0.21	0.40	ma	0.21	0.62	ur	0.28	0.69	dw	0.28	0.49
87-88	ma	0.16	0.23	dw	0.27	0.28	ur	0.29	0.46	ww	0.30	0.65			
88-89	ag	0.10	0.37	ur	0.20	0.41	dw	0.24	0.55	ma	0.29	0.67	ag	0.29	0.47